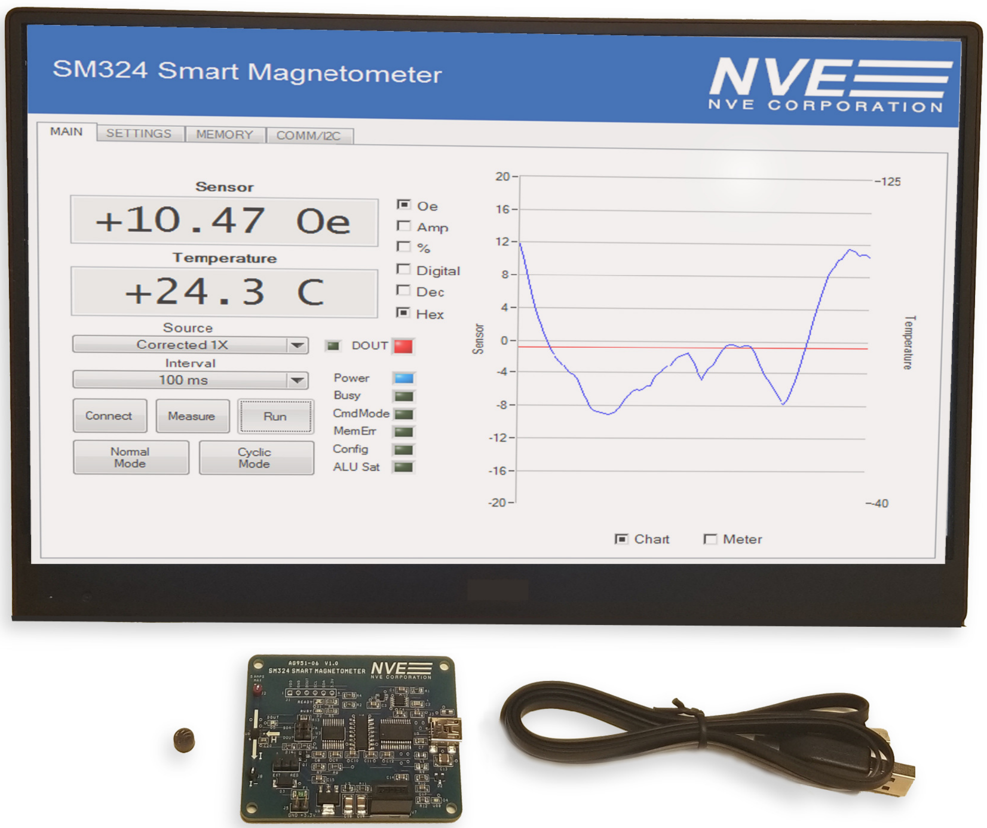
AG951: SM324 Ultraprecise Smart TMR Magnetometer Current Sensing/Proximity Sensing Demonstration Kit



Summary

The AG951 Demonstration Kit has everything you need to calibrate, test, and evaluate the remarkable SM324-10E Smart Magnetometer. The kit includes:

- USB-powered Demonstration Board with:
  - an SM324-10E Smart Magnetometer sensor
  - a microcontroller connected to the sensor via I²C
  - a current-carrying trace under the sensor for evaluating as a current sensor

- A powerful, intuitive graphical Windows-compatible user interface.
- Simple software installation.
- Flexibility to power from USB or external power supply.
- Isolated USB interface for safety and low noise.
- USB cable to connect the Demonstration Board to a computer.
- A small ceramic magnet for evaluating as a proximity sensor.

Contents

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1. Overview

SM324-10E Features:

- Can detect magnets more than 50 mm away
- I²C and digital threshold outputs
- 24-bit output resolution
- In-plane sensitivity more usable than Hall effect sensors
- Programmable offset and gain compensation
- Internal temperature compensation
- 1.68 – 3.6 volt supply
- Low-power sleep mode current (50 nA typical)
- Ultraminiature 2.5 x 2.5 x 0.8 mm TDFN package

SM324-10E Key Specifications:

- Excellent 1% accuracy over full temperature
- −2 mT to +2 mT (−20 to +20 Oe) range for high sensitivity
- 1.5 mA typical supply current for low power
- 300 Sps sample rate
- −40°C to +125°C operating range

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2. Quick Start

2.1. Install the software and launch the application.

2.2. Connect the Demonstration Board to a computer via the USB cable.

2.3. Apply a magnetic field with the disk magnet included in the kit and verify that the DOUT LED (D5) turns on:

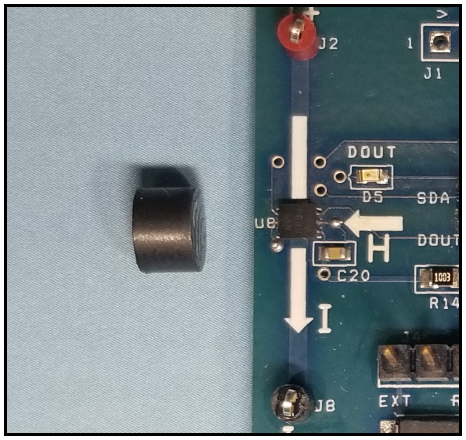

Figure 1. Activating the SM324 sensor with a disk magnet.

(NOTE: Since the sensor output only updates with each data request, the board must be connected and the software running for the threshold output to work).

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3. The Demonstration Board

3.1 Board Layout

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

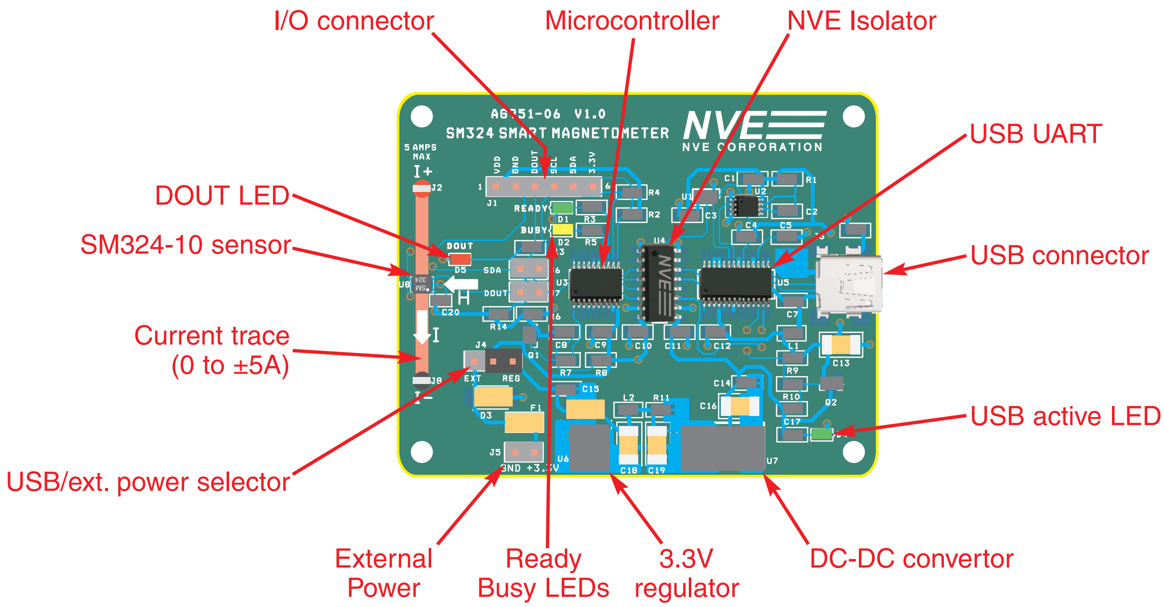

Figure 2. The Demonstration Board (actual size).

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3.2 Bill of Materials

Manufacturer Part Number	Reference Designator	Manufacturer	Quantity	Description
500401_1 SM324 Eval	N/A	NVE	1	Circuit Board 2.5" x 2"
GCM21BR71H104KA37K	C1,C3,C4,C5,C9,C10,C11,C12,C15,C17	Murata Electronics North America	11	CAP CER 0.1UF 50V X7R 0805
CL32B475KBUYNWE	C13	Samsung Electro-Mechanics	1	CAP CER 4.7UF 50V X7R 1210
CL32A106KPINNNE	C16,C18,C19	Samsung Electro-Mechanics	3	CAP CER 10UF 10V X5R 1210
GRM2165C1H102FA01D	C2	Murata Electronics North America	1	CAP CER 1000PF 50V C0G/NP0 0805
CL10B102JB8NNNC	C20	Samsung Electro-Mechanics	1	CAP CER 1000PF 50V X7R 0603
CL21B103KBANNNC	C7	Samsung Electro-Mechanics	1	CAP CER 10000PF 50V X7R 0805
GCM216R71H102KA37D	C8,C14	Murata Electronics North America	1	CAP CER 1000PF 50V X7R 0805
LTST-C193KGKT-5A	D1,D4	Lite-On Inc.	2	LED GREEN CLEAR CHIP SMD
LTST-C193KSKT-5A	D2	Lite-On Inc.	1	LED YELLOW CLEAR CHIP SMD
BZG05C3V6-HM3-08	D3	Vishay Semiconductor Diodes Division	1	DIODE ZENER 3.6V 1.25W DO214AC
LTST-C193KRKT-5A	D5	Lite-On Inc.	1	LED RED CLEAR CHIP SMD
0ZCJ0025AF2E	F1	Bel Fuse Inc.	1	PTC RESET FUSE 24V 250MA 1206
5000	J2	Keystone Electronics	1	TEST POINT PC MINI .040"D RED
690-005-299-043	J3	EDAC Inc.	1	CONN MINI USB RCPT RA TYPE B SMD
5-146285-3	J4	TE Connectivity AMP Connectors	1	CONN HEADR BRKWAY .100 3POS STR
146285-2	J5,J6,J7	TE Connectivity AMP Connectors	3	02 MODII HDR SRST B/A .100CL
5001	J8	Keystone Electronics	1	TEST POINT PC MINI .040"D BLACK
BK2125HS330-T	L1	Taiyo Yuden	1	FERRITE BEAD 33 OHM 0805 1LN
MLZ2012M100WT000	L2	TDK Corporation	1	FIXED IND 10UH 350MA 470 MOHM
DMP2100U-7	Q1,Q2	Diodes Incorporated	2	MOSFET P CH 20V 4.3A SOT23
RMCF0805FT73K2	R1	Stackpole Electronics Inc.	1	RES 73.2K OHM 1% 1/8W 0805
RMCF0805FT4K70	R2,R4	Stackpole Electronics Inc.	2	RES 4.7K OHM 1% 1/8W 0805
RMCF0805FT470R	R3,R5,R13	Stackpole Electronics Inc.	3	RES 470 OHM 1% 1/8W 0805
RMCF0805FT100K	R6,R8,R14	Stackpole Electronics Inc.	3	RES 100K OHM 1% 1/8W 0805
RNCP0805FTD1K00	R7,R10,R11,R12	Stackpole Electronics Inc.	4	RES 1K OHM 1% 1/4W 0805
RNCP0805FTD10K0	R9	Stackpole Electronics Inc.	1	RES 10K OHM 1% 1/4W 0805
SN74LVC1G02DCKR	U1	Texas Instruments	1	IC GATE NOR 1CH 2-INP SC70-5
SN74LVC1G123DCTR	U2	Texas Instruments	1	IC SNGL MONO MULTIVIBTOR SM8
R5F1026AASP#V5	U3	Renesas Electronics America	1	IC MCU 16BIT 16KB FLASH 20LSSOP
IL717-3E	U4	NVE Corp/Isolation Products	1	DGTL ISO 2.5KV GEN PURP 16SOIC
FT232RL-REEL	U5	FTDI, Future Technology Devices International Ltd	1	IC USB FS SERIAL UART 28-SSOP
UA78M33CDCYR	U6	Texas Instruments	1	IC REG LIN 3.3V 500MA SOT223-4
RO-0509S	U7	Recom Power	1	DC DC CONVERTER 9V 1W
QPC02SXGN-RC		Sullins Connector Solutions	3	CONN JUMPER SHORTING .100" GOLD
N/A	N/A	NVE	1	USB stick with PC install file

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3.3 Board Schematic

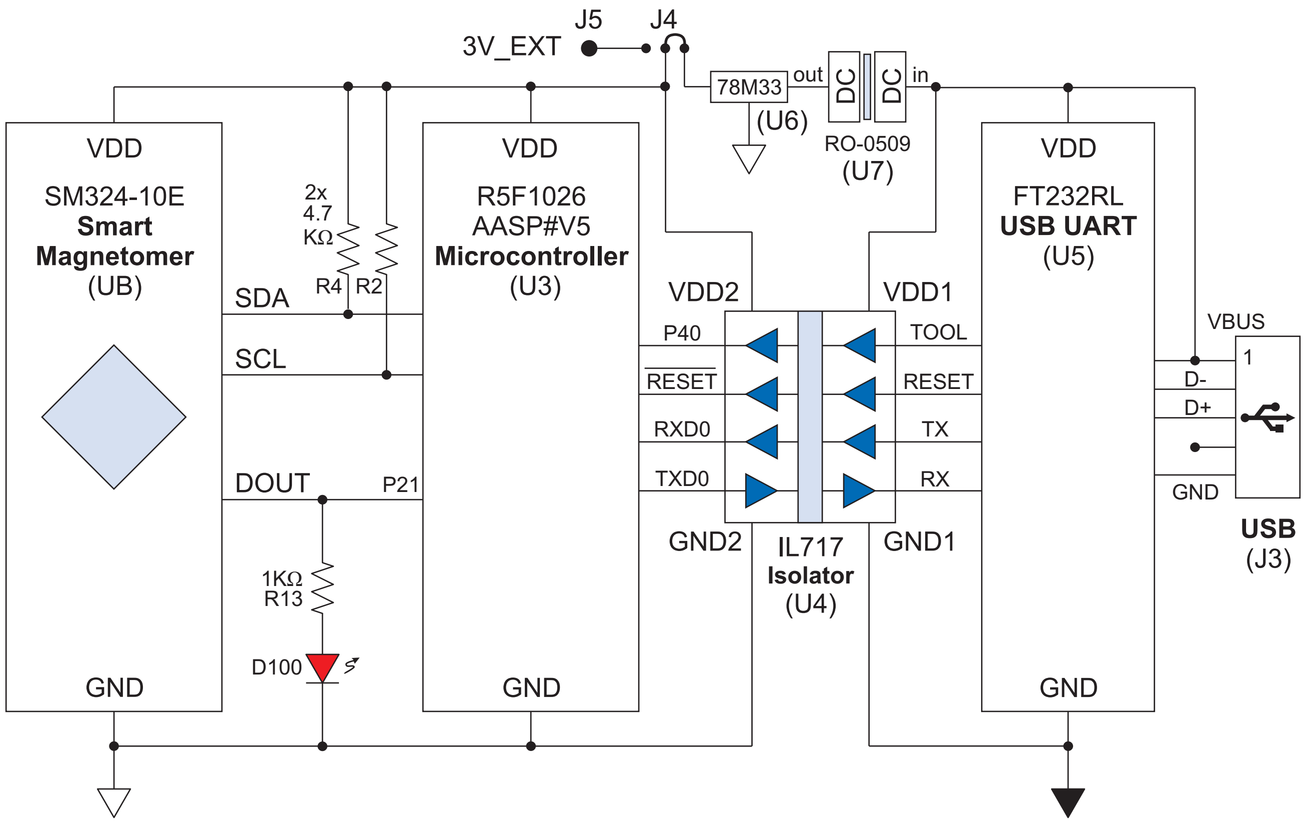

Figure 3. Simplified Board Schematic.

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3.4 Demonstration Board Circuit Description

The Sensor
The SM324-10E has five active pins, all of which are available on the demonstration board. The active pins are for power (VDD and GND); I²C (SCL and SDA); and the digital output (DOUT).

Microcontroller
The SM324 is compatible with almost any microcontroller. This board uses a popular Renesas RL78/G12 16-bit microcontroller (U3).

Current-Sensing Trace
The demonstration board includes a current-sensing trace for evaluating the magnetometer as a current-sensor. The trace is 0.05 inches (1.3 mm) wide and one-ounce copper, it can carry up to carry up to 7 amps indefinitely at room temperature with a safe temperature rise, and up to 10 amps for a few minutes.

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.

I²C
I²C links the sensor to the microcontroller. The SM324 is an I²C Slave, and the microcontroller is configured as the Master. The SM324 I²C interface is compatible with 3.3 or five-volt microcontrollers. The board uses 3.3 volts for both the sensor and microcontroller.

In accordance with industry standards, the SM324 SDA line is open-drain. The board has 4.7 kΩ pull-up resistors (R2 and R4) on SCL and SDA for maximum flexibility. In many cases, a microcontroller's internal pull-up resistors can be activated in software to reduce parts count.

When external pull-ups are used with different power supplies, they should be connected to the lower supply voltage.

The SCL and SDA test points can be connected to additional sensors, or to a user-supplied I²C bus for communication with the device.

Isolated USB Interface
A USB UART (U5) provides the computer interface. An IL717-3E isolator (U4) provides isolation from the board to the computer's USB. This eliminates ground-loop noise and any fear of damaging the computer. A DC-DC convertor (U7) and voltage regulator (U6) provide an isolated UART power supply.

LEDs
Red LED D5 shows when the digital output (DOUT) is activated. Green LED D1 indicates the microcontroller is active and yellow LED D2 indicates the microcontroller is running a command. Green LED D4 shows the USB bus has configured and powered the board.

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Power Supplies
The board can be powered by an external supply or by USB via an on-board DC-DC convertor. J4 selects the power source, and the optional external supply is connected to J5. Note that although the sensor will operate down to 1.68 volts, but other components on the board require a 3-volt minimum supply.

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.

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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:

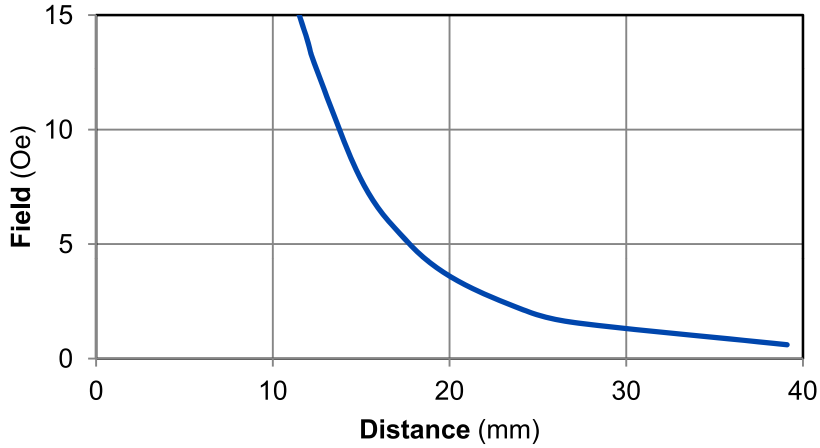

Figure 4. Magnetic field from the 6 mm dia. x 4 mm thick ferrite magnet.

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 20 Oe (2 mT), and commonly-used thresholds are 4 to 20 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 (50 µT).

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5. Current Sensing

SM324-10E 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 demonstration board includes a current-sensing trace:

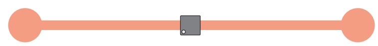

Figure 5. Current trace (top view).

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:

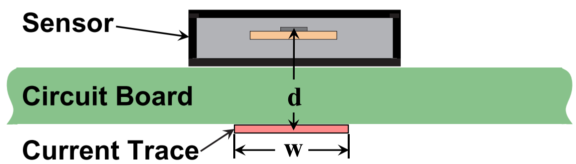

Figure 6. Current-sensing over a circuit board trace (side view).

$$H = \frac{2I}{d}$$ ["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 trace to the sensor element, which is 0.7 millimeters. The field is therefore approximately 2.8 Oe/amp.

More precise calculations for different trace configurations can be made by meshing the trace into a finite element array of thin traces and calculating the field from each array element. We have a free, Web-based application with a finite-element model to estimate magnetic fields and sensor outputs in this application:

www.nve.com/spec/calculators.php#tabs-Current-Sensing

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6. Hardware and Software Setup

6.1 Software Installation

6.1.1. The software system requirements are:

- Windows 7 or later
- USB 2.0 port

6.1.2. Install the software from the USB stick provided, or download the software installation package from ***https://github.com/NveCorporation***
Note: It is more reliable to install the Windows software before connecting the board to USB so the connection triggers automatic hardware discovery.

6.1.2. Connect the demonstration board to the PC using the USB cable. The interface should immediately show the sensor output.

6.2 Jumpers and Options

6.2.2. Powering the board using USB power:

6.2.2.1 Place a jumper on J4 in the right position (REG) to power the microcontroller and sensor using the regulated, isolated 3.3V supply.

6.2.2.2 The green LED labeled "*Ready*" should turn on indicating that the microcontroller is now powered and ready. If it does not, verify that jumper on J4 is installed correctly.

6.2.3. To use an external supply:

6.2.3.1. Connect an external 3V to 3.6V supply to the 3.3V and GND test points on either J1 or J5. Verify voltage and polarity are correct before powering on. If powering using the 3.3V test point on J1, ensure the jumper on J4 is set to the left (EXT) position or removed.

6.2.3.2. Power the external supply. The green LED labeled "*Ready*" should turn on indicating that the microcontroller is now powered and ready. If it does not verify that jumper on J4 is installed correctly.

6.2.4. Sensor selection:

6.2.4.1 To use the on-board SM324 sensor (U8) located over the current trace place jumpers on J6 (SDA) and J7 (DOUT).

6.2.4.2 To use an off-board sensor remove jumpers from J6 and J7. This disconnects the onboard sensor from the I²C bus and its DOUT output from the LED and microcontroller digital input. Connect an external SM324 sensor using the VDD, GND, DOUT, SCL, and SDA test points on J1.

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7. User Interface Operation

The User Interface allows reading sensor data, as well as reading and writing the nonvolatile sensor calibration memory.

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

1. Main – Displays measurements in digital and graphical formats.

2. Settings – Controls for easily setting the sensor and temperature offsets, sensor thresholds values, digital output configuration, cyclic measurement interval, and I²C address.

3. Memory – A table with the sensor's calibration constants. Also allows reading or writing the contents of the table to a file.

4. Comm/I²C – Controls communication with the demonstration board (USB) and sensor (I²C), along with miscellaneous functions.

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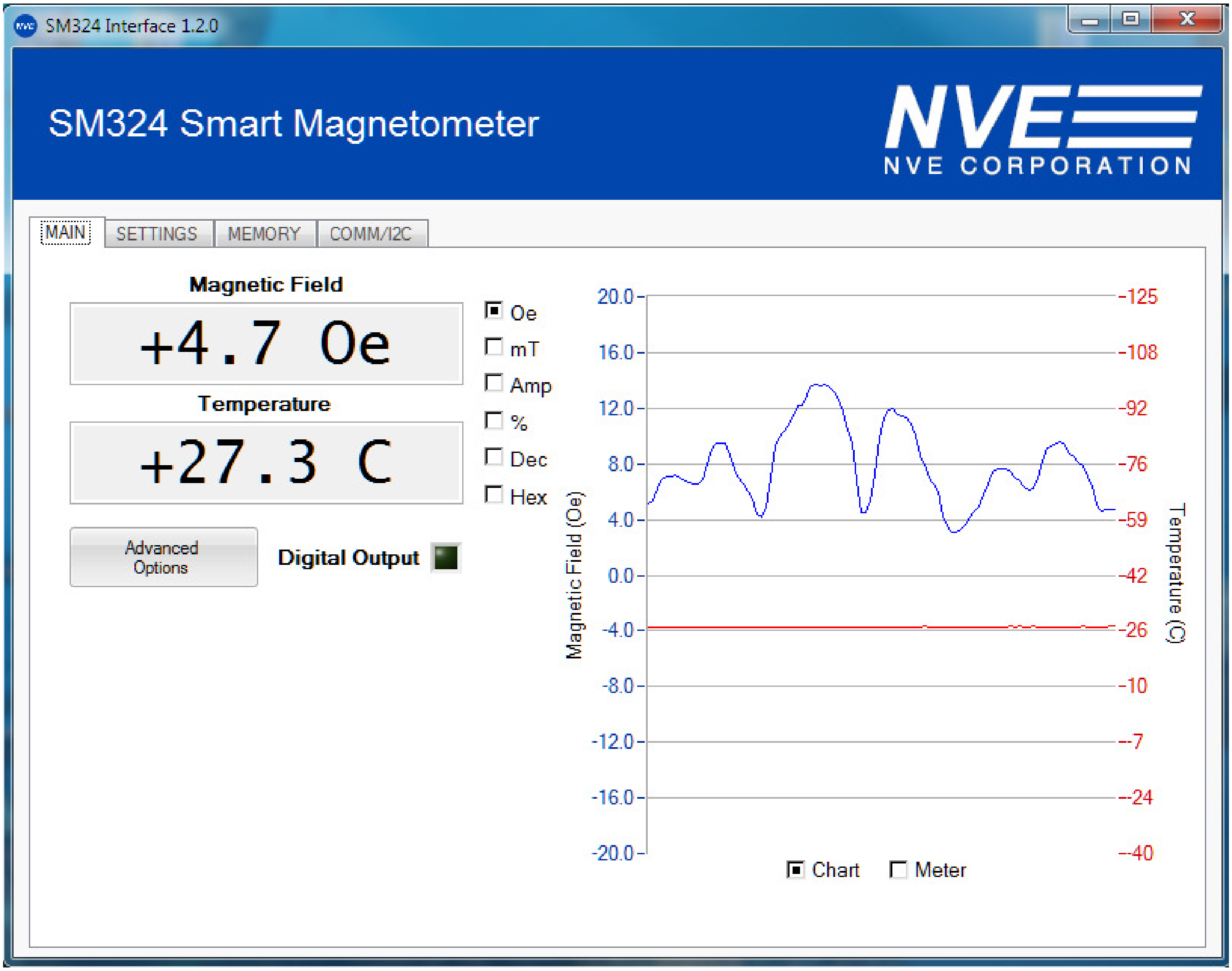
7.1. Main Tab



Magnetic Field Display – Displays the field measured by the in the selected units.

Temperature Display – Displays the output of the device's on-board temperature sensor in either degrees Celsius, percent of full scale, or as a 24-bit integer. Double right-clicking on the display changes the display precision.

Oe – Sets the *Magnetic Field* display units to Oersteds.

mT – Sets *Magnetic Field* display units to Millitesla (1 mT = 10 Oe in air).

Amp – Sets *Magnetic Field* display units to Amps, based on a calibration factor that can be changed in the *Settings* tab.

% – Displays *Magnetic Field* and *Temperature* as percentages of full scale.

Dec – Sets the *Field* and *Temperature* displays to show their 24-bit values in decimal.

Hex – Displays *Field* and *Temperature* in six-character hexadecimal format.

Chart – Displays a strip chart on right side of the tab showing the sensor and temperature measurement results on the y-axis and the sample number on the x-axis. The chart is updated with each measurement.

Meter – Displays a meter on the right side of the tab that shows the measurement result.

DOUT – Displays the status of the sensor's digital output DOUT (Red = on).

Advanced Options – Displays Advanced Options (see section 7.1.1 below).

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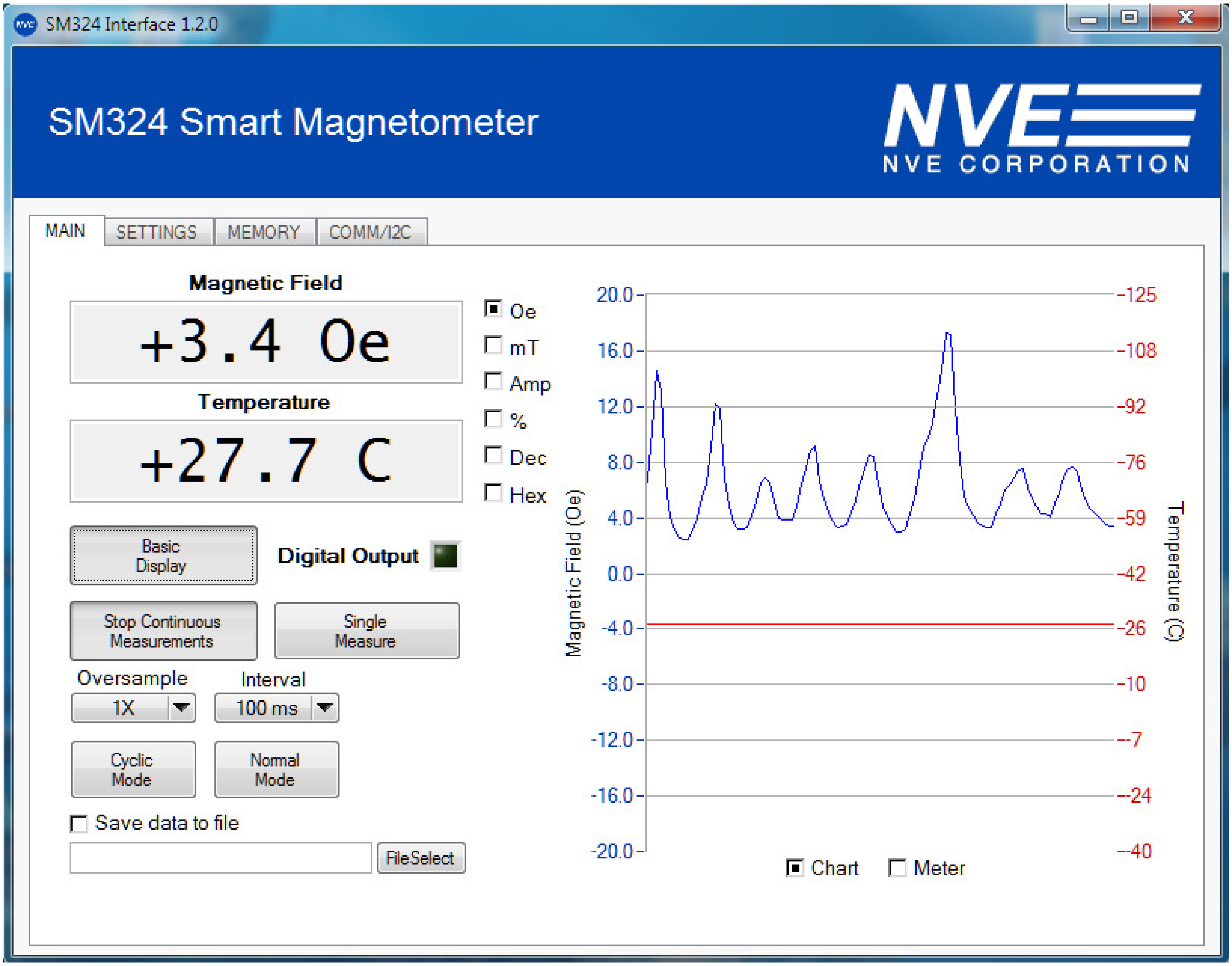
7.1.1 Advanced Options

This is how the *Main* tab appears with *Advanced Options* enabled:



Continuous Measurement – The normal mode of continuous updates.

Single Measure – Takes a single measurement and displays the results in the *Field* and *Temperature* displays, the *Meter* or *Chart* graphical display, the status of the sensor's digital output in the *DOUT* LED, and the data file if selected.

Oversample – Sets the number of samples the sensor's digital processor uses for each measurement.

Interval – Controls the software sampling frequency in continuous run mode.
Note: Actual interval times may be limited by system performance, I²C data rate, and oversampling.

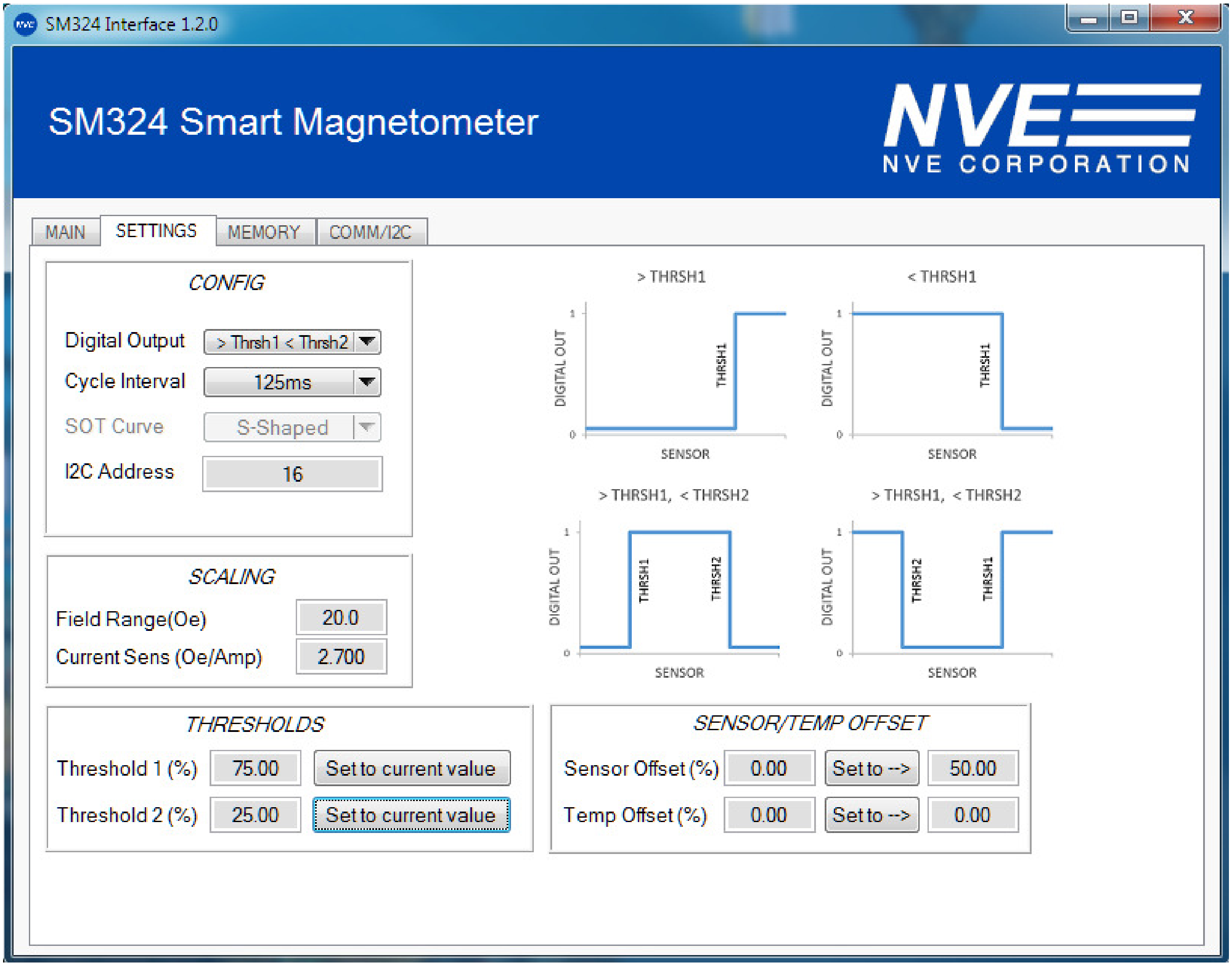
Normal Mode – The sensor updates its data and DOUT output when data is requested via I²C.

Cyclic Mode – The sensor's data and DOUT are updated at a rate defined in a parameter in sensor memory.

Save to data file – When checked sensor and temperature measurements will be saved to the selected CSV file. Data are time-stamped and saved with each sample as determined by the *Interval* control or the *Single Measurement* button. New data are appended to existing data in the file.

File Select – Selects a CSV file where measurements are saved. The selected file name will appear in the field next to the button.

7.2. Settings Tab



Config – This section can be used to set contents of config memory address 0x02.

- *Digital Output* (bits 8:7) – Controls functionality of the sensor's DOUT pin.
- *Cycle Interval* (bits 14:12) – Sets sensor's cyclic mode measurement interval.
- *I2C Address* (bits 6:0) – Sets the sensor's I²C address. Note: The sensor will respond to a newly written I²C address only after the next power-on reset (POR). Also, addresses 4 through 8 are reserved for high-speed I²C and not supported in this interface.

Scaling – This section controls how the digital output of the sensor is converted into physical units.

- *Field Range (Oe)* – Full-scale field range in units of Oersted (1 Oe = 0.1 mT). If set to 20 Oe, then a digital output of 0x000000 (0%) will be interpreted as –20 Oe, a digital output of 0x800000 (50%) will be interpret as 0 Oe, and a digital output of 0xFFFFFF (100%) will be interpreted as +20 Oe.

- *Current Sens (Oe/Amp)* – When using the sensor to detect electrical current this value converts the measured field into units of Amps. This value is dependent on the geometry and spacing of the sensor to current source. The default value is the typical sensitivity for the demo board trace and sensor spacing.

Thresholds – This section can be used to set the threshold values at which the sensor's digital output (DOUT) turns on or off. Changing values in this section will write to memory addresses 0x13, 0x14, and 0x15.

To manually change the thresholds, enter a percent of full-scale value (0–100%) into the numeric field next to each threshold. This will calculate and write the contents to the associated memory addresses.

Alternatively, the thresholds can be set to the field level present at the sensor. To do this set the magnetic field source to the desired position or value and press *Set to current value*. The threshold will be set and the numeric field will be updated.

Note: The thresholds will only affect the digital output of the sensor if enabled in the *Digital Output* control in the *Config* section.

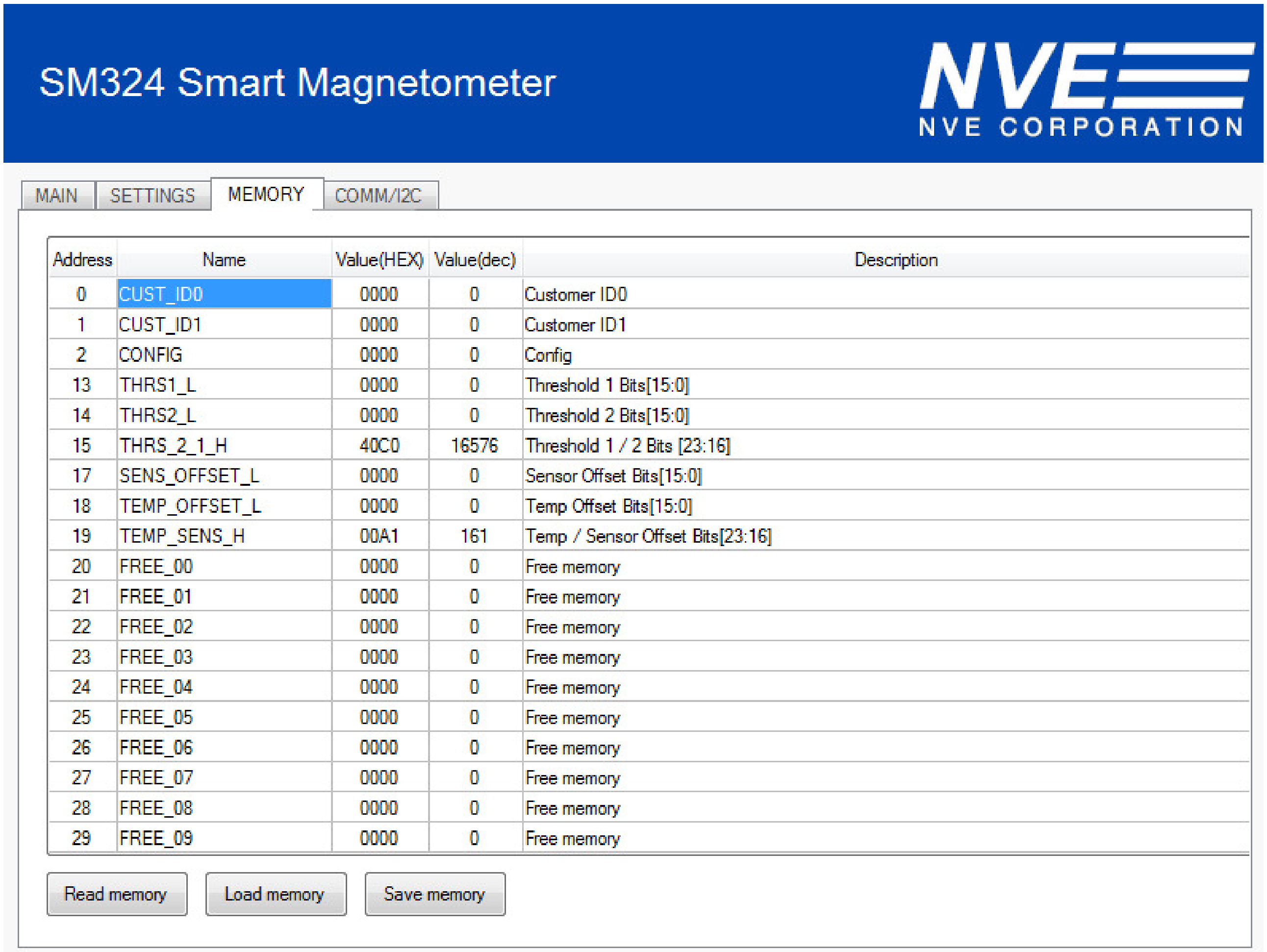
Sensor/Temp Offset – This section can be used to set the sensor and temperature offsets, useful for zeroing out background magnetic fields. Changing values in the left numeric fields will write to memory addresses 0x17, 0x18, and 0x19.

To manually set the offsets enter a percent of full-scale shift (−50% to +50%) into the numeric field next to either the *Sensor Offset (%)* or *Temp Offset (%)* labels. This will calculate and write the contents to the associated memory addresses. A positive value will shift the measured sensor or temperature positive by that percent and vice versa.

Alternatively, the offsets can be set so that the measured outputs match a predefined value, i.e., zeroing out background magnetic field. To do this set the magnetic field source to the desired position or value, enter the desired output value into the right numeric field, and press the "Set to →" button. The offset shift needed to match the desired value will then be calculated and written to the associated memory addresses as well as the left numeric field.

Example: The sensor produces an output of 52% with no field present. To zero it to 50%, enter "50.00" into the right field and press "Set to →". A –2% shift will be put into the left numeric field and written to the sensor memory, and the sensor will now output 50%.

7.3. Memory



Address	Name	Value(HEX)	Value(dec)	Description
0	CUST_ID0	0000	0	Customer ID0
1	CUST_ID1	0000	0	Customer ID1
2	CONFIG	0000	0	Config
13	THRS1_L	0000	0	Threshold 1 Bits[15:0]
14	THRS2_L	0000	0	Threshold 2 Bits[15:0]
15	THRS_2_1_H	40C0	16576	Threshold 1 / 2 Bits [23:16]
17	SENS_OFFSET_L	0000	0	Sensor Offset Bits[15:0]
18	TEMP_OFFSET_L	0000	0	Temp Offset Bits[15:0]
19	TEMP_SENS_H	00A1	161	Temp / Sensor Offset Bits[23:16]
20	FREE_00	0000	0	Free memory
21	FREE_01	0000	0	Free memory
22	FREE_02	0000	0	Free memory
23	FREE_03	0000	0	Free memory
24	FREE_04	0000	0	Free memory
25	FREE_05	0000	0	Free memory
26	FREE_06	0000	0	Free memory
27	FREE_07	0000	0	Free memory
28	FREE_08	0000	0	Free memory
29	FREE_09	0000	0	Free memory

Memory tab elements are described below:

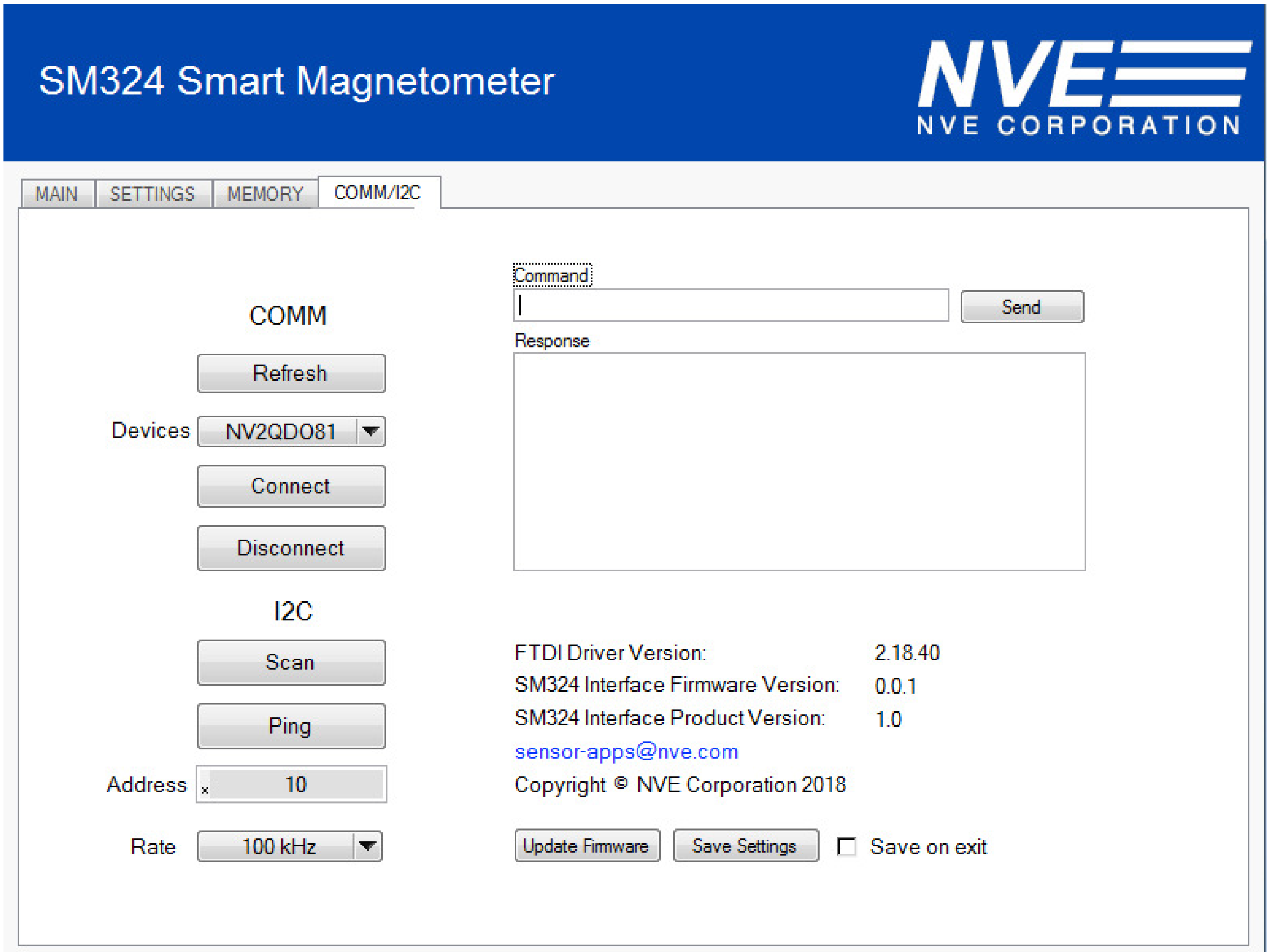
Table – Contains a listing of user memory addresses including address in hexadecimal format, name, value in hexadecimal and decimal format, and a description. Memory addresses may be written to directly by entering a value into the table. Factory-set addresses are not displayed in this interface.

Read memory – This will read the contents of the sensor memory to ensure values in the *Settings* and *Memory* tabs are up-to-date.

Load memory – This will prompt the user to select an XML formatted memory file to load and write to the sensor. After loading and writing it will read back the contents into the table.

Save memory – This will prompt the user to select a file for writing the contents of the memory table. A *Read memory* should be performed before saving to ensure the contents of the saved match that stored in the sensor.

7.4. Comm/I2C Tab



Refresh – Scans USB ports for connected boards and displays their serial number in the *Devices* list.

Devices – Displays connected boards found using *Refresh* button.

Connect – Connects to the board selected in the *Devices* list using the I²C address and data rate in the *Address* and *Rate* controls. The driver, firmware, and product revisions of connected devices are read and displayed.

Command – Field for entering commands to be sent to the board for microcontroller configuration and reading/writing to SM324 I^2C. See Section 7.5 for more information on the USB serial communication protocol. Leading and terminating characters (0x02, 0x03) will be added by software and should be omitted.

Send – Sends the command entered in the *Command* string to the microcontroller.

Response – Displays response for the command sent.

Scan – Causes the microcontroller to step through all valid I²C addresses, starting with zero, until a device responds to that address. If more than one sensor is attached to the I²C bus, the address should be set manually using the *I²C Address* control.

I²C Address – Writing to this control updates the I²C address the microcontroller will use to communicate with the sensor. The value ranges from 8 to 127 and represents the upper seven bits of the device address byte written over the I²C bus.

Ping – Attempts a single read from the address set by the *I²C Address* control. This can be used to verify the address matches the attached sensor's slave address.

Rate – Sets the clock rate of the I²C bus.

Save Settings – Writes software settings (I²C address and rate, formats, units, file path names) to an INI file in a user-specified directory. The software will load the INI file from this directory on startup unless a new directory is selected.

Save on exit – If set the software on program exit will write the current settings to the active INI file directory (selected using *Save Settings*). If no new directory has been selected, it will save the values to the current working directory containing the executable.

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7.5. Serial USB Communications

The demonstration board appears as a virtual COM port to the PC. This allows communications with any terminal or serial communication software. In addition, the *Command* field on the COMM/I2C tab can be used to send commands directly to the microcontroller. This section defines the COM settings and protocol for communicating with the board.

The virtual COM port settings are summarized in the following table:

Baud Rate	115200
Data bits	8
Parity	None
Stop bits	1
Flow control	None

Table 1. Virtual COM port settings.

The communication protocol uses ASCII characters for ease of debugging. Commands sent to the board are variable in length and include a leading character STX (ASCII character 0x02) and a terminating character ETX (ASCII character 0x03). Responses from the board are always 16 bytes long, including the leading character STX and terminating character ETX.

The first character of any command following the leading character are one to two command characters ("W," "R," "AA," etc.) followed by zero to several hexadecimal values in ASCII format (e.g., "W06001F"). The entire command string, including leading and terminating characters, for this example will then be "/02W006001F/03."

A complete listing of commands, responses, and error codes can be found in the *SM324 Interface Communication.xlsx* spreadsheet included in the *Documents* folder of the software install directory.

8. Troubleshooting

- USB inactive (green "USB" LED inactive).
  - Check USB cable.
  - Reinstall the software.

- Green "Ready" LED not active.
  - Verify jumper J4 is installed.

- Red "DOUT" LED doesn't turn on in the presence of a magnetic field.
  - Ensure the board is connected to the computer and the software is running (since the sensor output only updates with each data request, the software must be running for the device output to work).
  - Ensure thresholds are programmed in a reasonable range.

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9. Revision History

SB-00-078-B
September 2019

Change
- Streamlined User Interface.

SB-00-078-A
September 2018

Change
- Initial Release.

SB-00-078-PRELIM
July 2018

Change
- Preliminary Release.

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