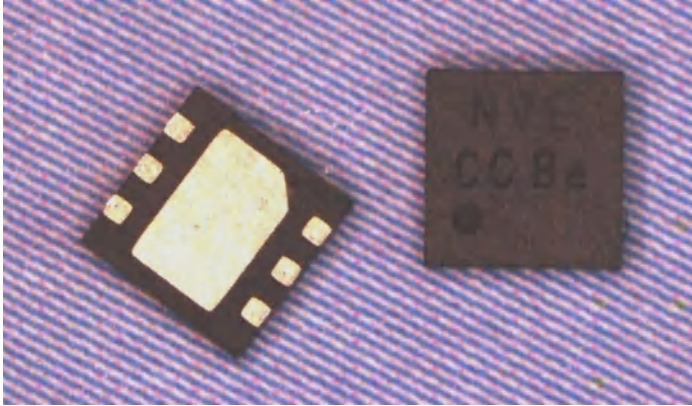


SM12x-10E GMR Smart Magnetometers



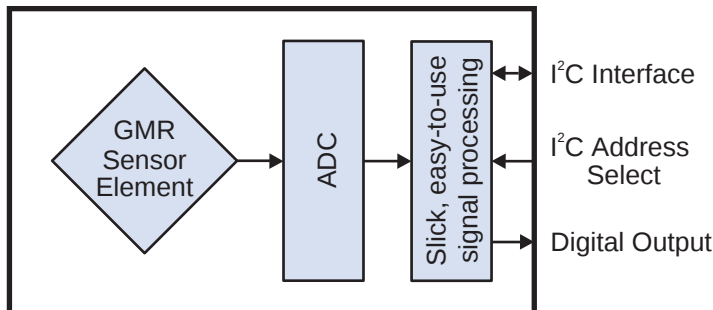
Features

- 0 to 1 mT (SM124) or 0 to 4 mT (SM125) linear ranges
- Can detect magnets more than 50 mm away
- Slick, single-byte communication interface
- Analog field measurement plus on/off digital output
- Internal temperature compensation
- Factory calibrated
- Programmable offset and gain correction
- Programmable I²C address
- In-plane sensitivity—more usable than Hall effect sensors
- Optional magnet temperature compensation
- 2.2 to 3.6V supply
- 3.3 or 5 V compatible I²C interface
- Ultraminiature 2.5 x 2.5 x 0.8 mm TDFN6 package

Key Specifications

- 8 bit / 1% output resolution
- -40 °C to +125 °C operating range
- 5% FS accuracy for 0 to 85 °C
- 10 kSps sample rate for fast response

Simplified Block Diagram



Applications

- Mechatronics
- Proximity sensing
- Level sensing
- Current sensing
- Security and intrusion detection
- Automotive applications
- Cylinder position sensing

Description

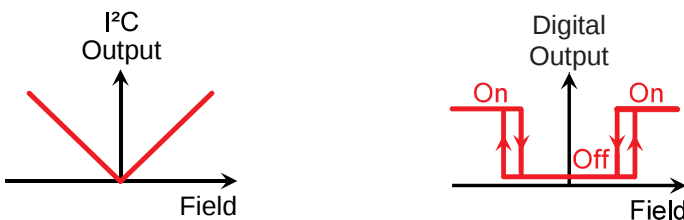
SM12x Smart Magnetometers provide precise magnetic field measurements. The sensors combine Giant Magnetoresistance (GMR) sensor elements with easy-to-use digital signal processing.

Unlike awkward, old-fashioned Hall-effect sensors, GMR is sensitive in-plane for optimal current sensing and easy mechanical interfaces. GMR also provides more sensitivity, higher precision, higher speed, and lower noise than Hall.

A digital output provides precise, programmable thresholds. An I²C interface provides magnetic field data, as well as a calibration interface. The device is factory calibrated for high accuracy. Calibration coefficients are stored in internal nonvolatile memory.

All commands, data, and coefficients are a single byte, and a slick, elegant data structure lets you get up and running with a minimum of firmware.

Transfer Functions



Absolute Maximum Ratings

Parameter	Min.	Max.	Units
Supply voltage	-0.3	4.2	Volts
Output current	-100	100	mA
SCL and SDA input voltages	-0.5	$V_{CC} + 2.5$ up to 5.8	Volts
Storage temperature	-55	150	°C
ESD (Human Body Model)		2000	Volts
Applied magnetic field		Unlimited	Tesla

Recommended Operating Conditions

	Symbol	Min.	Typ.	Max.	Units
Operating temperature	$T_{min}; T_{max}$	-40		125	°C
Supply voltage	V_{DD}	2.2	3.3	3.6	V

Operating Specifications

T _{min} to T _{max} ; 2.2 < V _{DD} < 3.6 V unless otherwise stated.							
Electrical	Symbol	Min.	Typ.	Max.	Units	Test Condition	
Supply current	I _{DD}		6	7	mA	max. at V _{DD} = 3.6V	
Power-on Reset supply voltage	V _{POR}		1.4		V		
Brown-out power supply voltage	V _{BOR}	0.75	1	1.36	V		
Digital out high voltage	V _{OH}	V _{DD} – 0.7			V	I _{OH} = –5 mA	
Digital out low voltage	V _{OL}	0.5			V	I _{OL} = 15 mA	
Magnetics							
Linear range					mT	Omnipolar (fields of either polarity)	
SM124		0		1			
SM125		0		4			
Saturation							
SM124		1.2	1.4				
SM125		4.5	5				
Resolution	δH				% FS	0 to 85°C, Unipolar –40 to 125°C, Unipolar SM125, 3 to 4 mT, 0 to 85°C, Unipolar	
SM124			0.01				
SM125			0.04				
Accuracy (% of linear range)				±5			
				±10			
				±15			
Precision and Speed							
Resolution			±1		%		
Digital precision			7		bits		
Sample rate			10		kSps		
Output response time			85		µs		
Start-up time	T _{STA}		15		ms		
Internal Temperature Sensor							
Temperature accuracy (factory calibrated)				±2.5	°C	25 to 85°C	
				±5	°C	–40 to 125°C	
I ² C Interface							
Data transfer rate	DR			400	kBaud		
Bus voltage	V _{BUS}	2.2		5.5	V		
Output response and transmission times				20	µs	400 kBaud	
Low level input threshold voltage	V _{IL}	0.8			V		
High level input threshold voltage	V _{IH}			2.2	V		
Low level output current	I _{OL}	3			mA	V _{OL} = 0.4V	
I/O capacitance	C _{I/O}			10	pF		
RAM Timing							
Address setup time	t _{ADDR}	3			µs		
Data read time	t _{READ}	10			µs		
Nonvolatile Memory Characteristics							
Address setup time	t _{ADDR}	3			µs		
Data read time	t _{READ}	10			µs		
Data write time	t _{NVM}	20			ms		
Endurance			10000		Cycles		
Package Thermal Characteristics							
Junction-to-ambient thermal resistance	θ _{JA}		320		°C/W		
Package power dissipation				200	mW		

SM124 Overview

Direction of Magnetic Sensitivity

As the field varies in intensity, the digital output will turn on and off. Unlike Hall effect and other sensors, the direction of sensitivity is in the plane of the package. The diagrams below show two permanent magnet orientations that will activate the sensor in the direction of sensitivity:

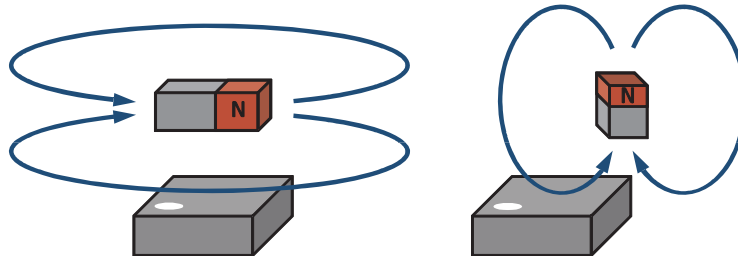


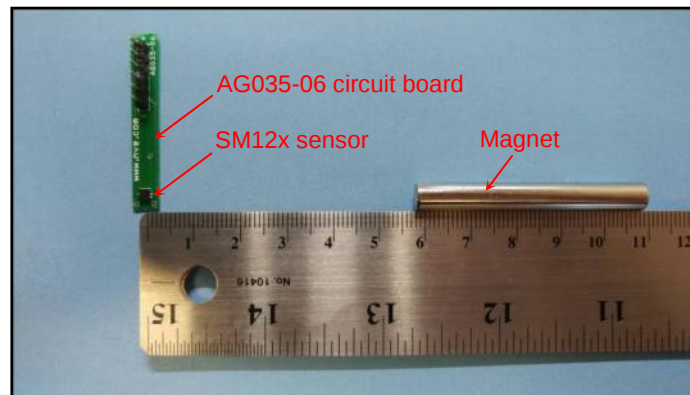
Figure 1. Direction of magnetic sensitivity.

The axis of sensitivity is in the pin 2 to pin 5 sensor axis, which is ideal for position sensing or current sensing so a current-sensing trace can be run under the sensor without crossing the pins. These sensors are “omnipolar,” meaning the output is positive for either magnetic polarity, simplifying systems where the magnetic polarity is not known.

Typical Operation

Position Sensing

A typical proximity sensor using an SM12x-10E sensor and magnet is shown below. With a 0.4 mT operate point, the sensor actuates with a rare-earth magnet at more than 50 mm (two inches) from the sensor:



**Figure 2. SM12x-10E sensors can be activated by a magnet more than 50 mm away.
Maximum sensitivity is in plane with the sensor, with the magnet axis in the pin 2/pin 5 sensor axis.
The part is sensitive to either north or south fields.**

Thresholds even lower than 0.4 mT can be programmed, although care must be taken to account for the earth’s magnetic field, which is typically in the 0.05 mT range.

Typical magnetic operate distances for SM12x sensors are illustrated in the following graph with a small, inexpensive ceramic disk magnet:

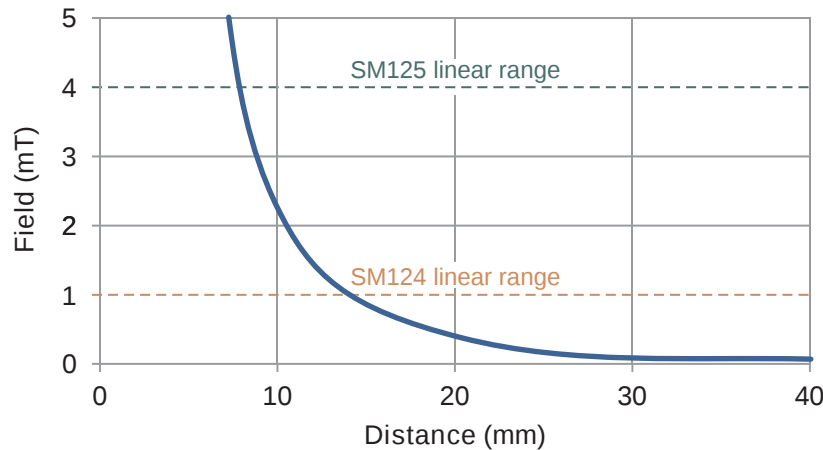


Figure 3. Field vs. distance from the center of the sensor
(NVE part number 12216 ferrite magnet; 6 mm dia. x 4 mm thick; C1/Y10T; $M_s=B_r=2175$ G).

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.

Noncontact 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. The sensor is ideal for these applications because of the low fields generated. The digital output can be used for current threshold detection or overcurrent protection.

Typical current sensing configurations are shown below:

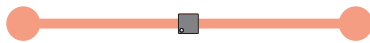


Figure 4a. 0.05" (1.3 mm) trace on top of PCB
(0.28 mT/amp; 10 A max.).

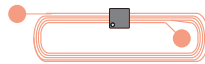


Figure 4b. Five-turn, 0.0055" (0.14 mm) trace on top of PCB
(1.4 mT/amp; 1 A max.).

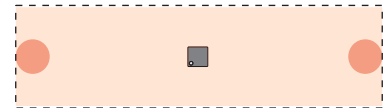


Figure 4c. 0.5" (13 mm) trace on bottom of 0.15" (3.8 mm) thick PCB
(0.04 mT/amp; 50 A max.).

For the geometry shown below and narrow traces, the magnetic field generate can be approximated by Ampere's law:

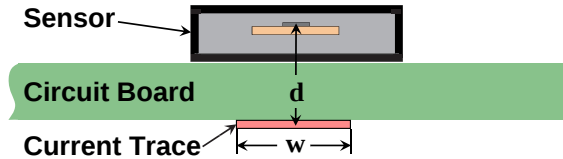


Figure 5. The geometry of current-sensing over a circuit board trace.

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

For traces on the top side of the board, "d" is simply the distance of the sensor element from the bottom of the package, which is 0.5 millimeters.

Traces on the top side of the board are typically used for currents of five amps or less. Large traces on the bottom side of the PCB can be used for currents of up to 30 amps.

More precise calculations can be made by breaking 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

Operation

A detailed block diagram is shown below:

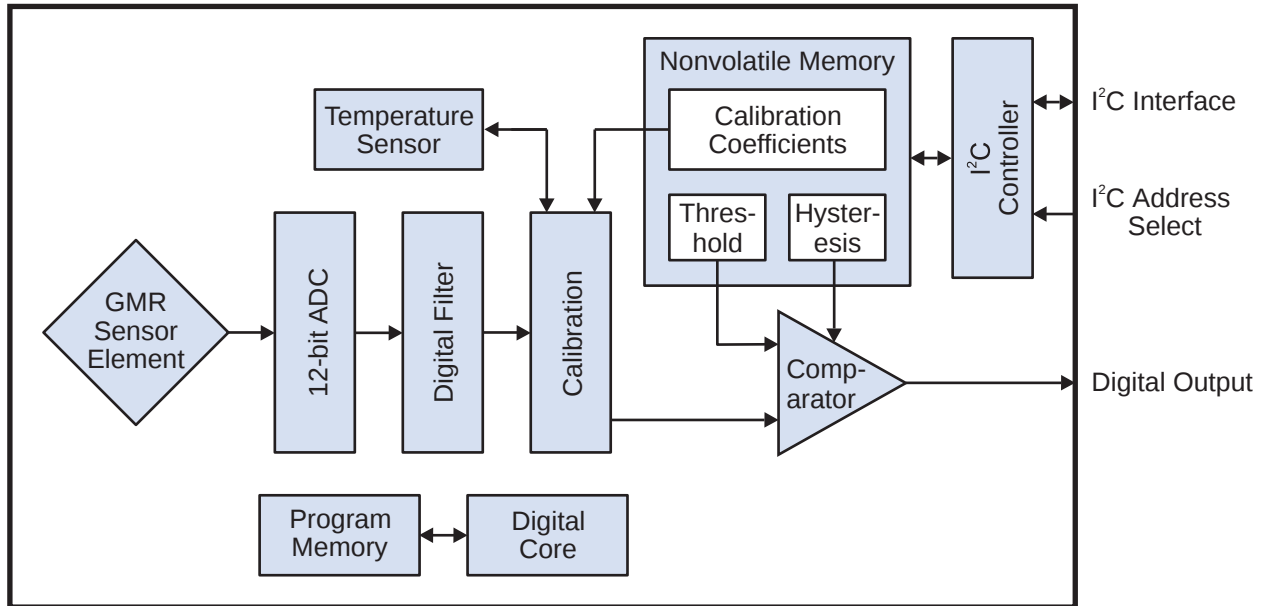


Figure 6. SM12x detailed block diagram.

Sensor Element

SM12x sensors use unique GMR sensor elements that are inherently high sensitivity, high speed, and low noise.

ADC

The sensor output is digitized with an eight-bit ADC.

Digital Filter

A first-order Infinite Impulse Response (IIR) digital filter with a programmable cutoff frequency can be used for ultralow noise if high-frequency operation is required. The factory default is the filter turned off.

Single-Byte Addresses, Data, and Parameters

All data and parameters are input and output as single bytes (eight bits). This provides at least 1% precision while eliminating the need to concatenate upper and lower bytes.

No Communications Overhead

Data are always valid, so there is no need to wait for data during an I²C read, and there are no set-up commands or error handling required.

Sensitivity and Offset Calibration

The sensor element is factory calibrated for sensitivity, offset, linearity, and temperature compensation. The user can also calibrate the output for a particular system.

A sensor calibration curve is illustrated below:

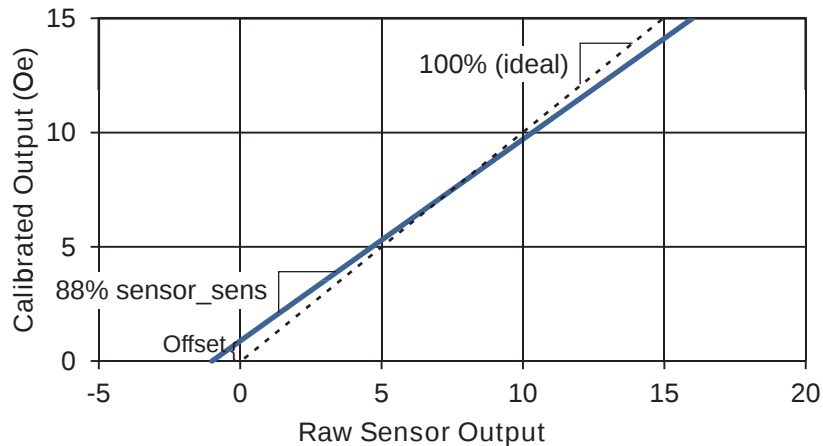


Figure 7. Illustrative SM124 sensor calibration curve.

There are two sensor calibration parameters, sensitivity and offset. Sensitivity is expressed as a percentage of nominal; offset is expressed as bits out of seven bits full scale. Calibration parameters are stored in nonvolatile memory, and can be read or written via I²C.

Mathematically, the corrected sensor output is calculated as follows:

$$\text{sensor} = ((\text{temperature}) * \text{tempco} / 100000 + 1) * (\text{sensor_raw}) / \text{sensor_sens} - \text{sensor_offset}$$

where “sensor” is the corrected sensor output, “temperature” is the measured temperature in °C, and the other operands are parameters provided from factory calibration. “tempco” is expressed in %/1000°C and as a positive number for convenience although GMR actually has a negative temperature coefficient, meaning it is less sensitive at higher temperatures.

Magnet Temperature Compensation

There are optional magnet temperature profiles that also compensate for the loss of magnetic field strength as temperature increases. Two profiles are available: one for low-cost ferrite magnets and another for high field rare-earth magnets. Writing to address 0x2B sets the compensation profile: “0” is the default profile and provides no magnet temperature compensation; “1” compensates for ceramic or ferrite magnets, and “2” compensates for NdFeB or rare-earth magnets.

Temperature Sensor

An internal temperature sensor is used to compensate the sensor element, and the temperature sensor itself is factory calibrated for slope and offset. Like magnetic field, temperature can be read via I²C and can also be user calibrated.

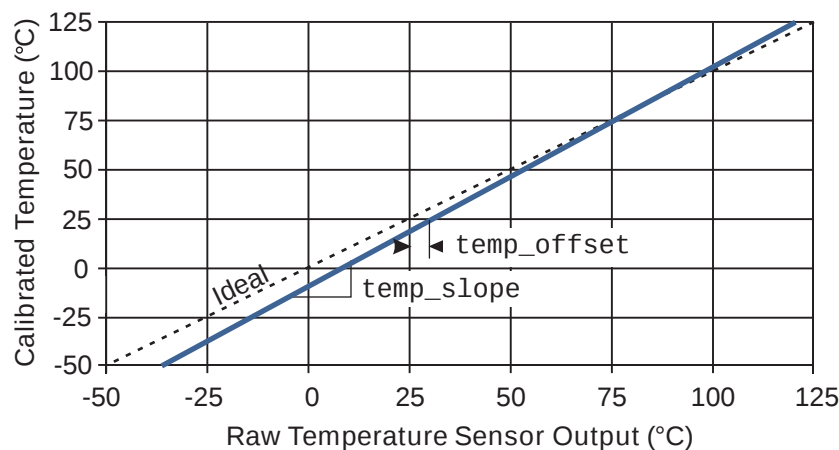


Figure 8. Temperature sensor calibration.

Mathematically, temperature is corrected as follows:

$$\text{temperature} = (\text{temperature_raw}) * 100 / \text{temp_slope} + \text{temp_offset}$$

where “temp_offset” is the temperature error at 0°C (positive indicating the sensor reads low); and temp_slope is the temperature sensor sensitivity expressed as a percent of ideal; greater than 100% indicates the sensor reads high.

Comparator and Digital Output

A digital comparator drives a CMOS Digital Output (“DOUT”)

Default Mode

By default, DOUT goes HIGH when the sensor field exceeds a threshold (THRSH; also known as THRSH_L), then LOW when the field magnitude drops below the threshold minus hysteresis as illustrated below:

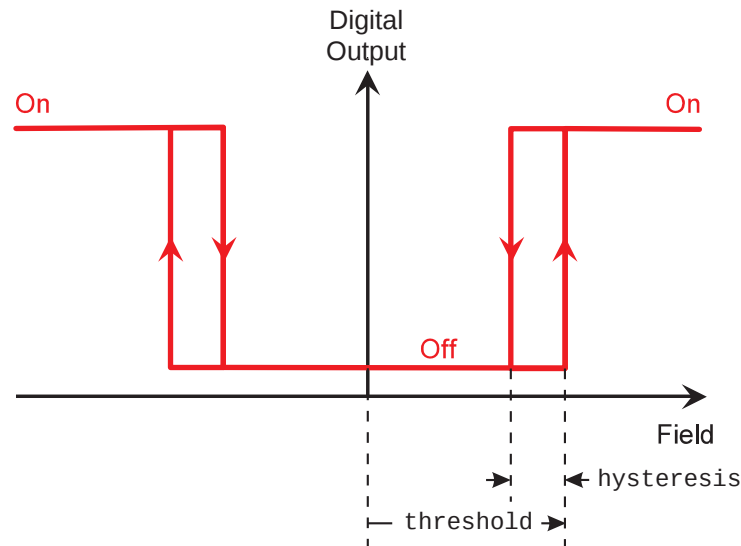


Figure 9. Default Digital Output parameters.

THRSH_H is unused in this mode, and can be set to 255 (dec).

Latching Mode

In the default mode (THRSH_H = 255) with HYST greater than THRSH, DOUT will latch ON when the field exceeds the threshold. A HYST value of 255 (dec) can be used to ensure the latching mode. The output can be reset by setting it to zero via I²C or by cycling the sensor power. Latching mode can be used to implement a “virtual circuit breaker” for overcurrent protection.

Window Comparator Mode

(Note: The Window Comparator Mode is only available in sensor lot codes 1932xx and higher.)

The window comparator mode is useful for certain mechatronics, and in security applications where a low field indicates intrusion and a high field can indicate magnetic tampering.

This mode has two thresholds (THRSH_L and THRSH_H):

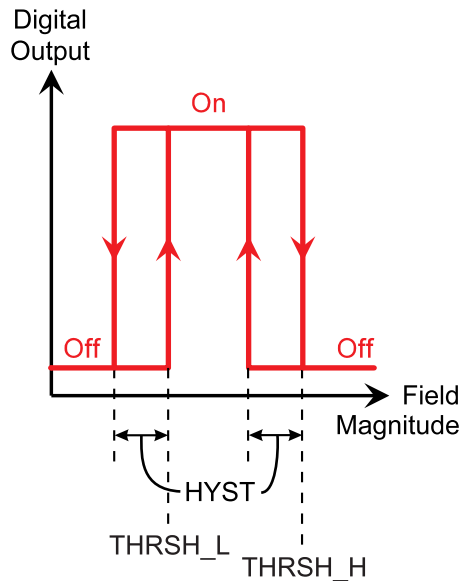


Figure 10. Window comparator mode.

Operation is the same for positive or negative fields, since the sensor is sensitive to field magnitude, not polarity.

Digital Output Operation

Unlike some other parts, the digital output is continuously updated at high speed and runs independently of the I²C interface. The SM12x can therefore be used with factory defaults or customer programmed Digital Output parameters without an I²C connection.

Threshold and hysteresis parameters are expressed as percentages of the sensor's linear range and are stored in nonvolatile memory. Threshold parameters can be set once for the life of the device if desired.

The "DOUT_invert" parameter can be set to invert DOUT. DOUT is a high-current push-pull output, with especially high current-sinking capability. Inverting DOUT and connecting an LED, relay, or other load between V_{DD} and DOUT takes advantage of the Digital Output's strong current-sinking capability.

Graceful Saturation

Unlike other magnetic sensor technologies, GMR sensing elements gradually saturate at high fields, rather than suddenly becoming unresponsive. This allows over-field sensing if high accuracy is not required, such as detecting tamper fields or high fault currents. The linear range is 1 mT for the SM124 and 4 mT for the SM125 and correspond to output values of 100. However, the sensors typically do not saturate until 110% to 120% of the linear range. The digital resolution extends to 255, which allows measurements all the way to saturation.

The typical magnetic response is illustrated below:

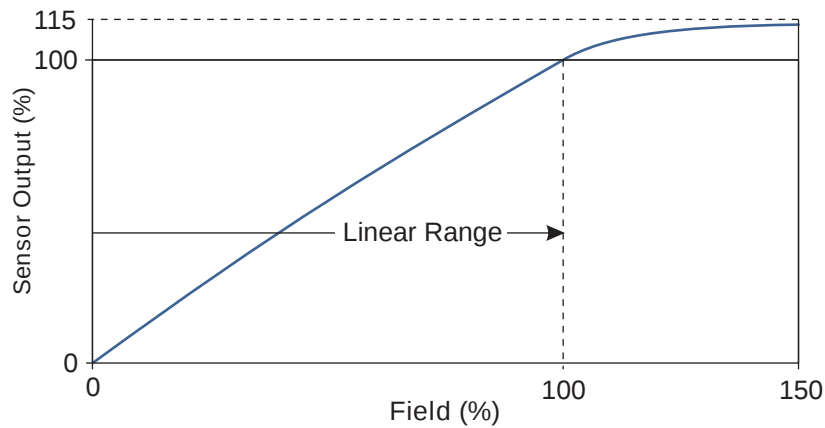


Figure 11. Graceful sensor saturation.

Temperature Compensation

SM12x sensors compensate for an inherent slight decrease in GMR sensitivity with temperature. Each sensor is factory calibrated and does not normally need to be recalibrated. If necessary, however, the temperature coefficient can be rewritten, or the user's sensor system can be calibrated based on a coefficient incorporating the change in magnet strength with temperature.

The sensor also has built-in options to compensate for magnet strength degradation with temperature using established residual induction temperature coefficients. Two corrections are available: one for ferrite ceramic magnets, and the other for neodymium rare-earth magnets.

Restoring Factory Calibration

Writing a "1" to sensor memory location 0x7 restores factory calibration settings. This does not change the I²C address back to the factory default.

I²C Interface

The I²C interface is an industry standard full-duplex 400 kHz connection with the sensor as the slave. I²C Data (SDA) and Clock (SCL) are 3.3- and five-volt compliant.

Consistent with industry practice, SDA is open-drain, and a pull-up resistor to V_{DD} is normally needed.

A schematic of a typical 3.3- or five-volt microcontroller interface is shown in the "Typical Circuit" section of this datasheet.

Factory Programming

Factory programming of any parameters is available. Contact us for details.

Applications Information

Minimizing Noise

Several steps allow taking advantage of the SM12x's inherent low noise:

- Inadequate bypassing can cause noise or anomalous device behavior. 10 μ F total bypass capacitance is recommended. To minimize magnetic field disruption, a small (e.g., 0201 / 0603 metric or 01005 / 0402 metric) 0.1 μ F ceramic capacitor can be placed as close as possible to the V_{DD} and GND pins with a 10 μ F ceramic capacitor a few millimeters away. The small capacitors contain very little ferromagnetic material.
- Use a circuit board ground plane.
- If the sensor is not being used for current over trace sensing, ground the sensor's center pad so the leadframe acts as a shield.

Minimizing Magnetic Interference

Several precautions can be taken for applications requiring the best accuracy:

- Components such as resistors and capacitors are generally slightly magnetic, and should be located at least several millimeters from the sensor. Such components should not be placed between magnet and the sensor.
- If components must be located near the sensor, ultrasmall components such as 0201 / 0603 metric or 01005 / 0402 metric contain less ferromagnetic material than larger components.

Although they are expensive, nonmagnetic resistors and capacitors can be used for extremely sensitive applications. A nonmagnetic 0.1 μ F bypass capacitor can be used close the sensor, with a conventional 10 μ F ceramic capacitor at least several millimeters away.

Changing the I²C Address in Nonvolatile Memory

The default I²C address is stored in nonvolatile memory, and can be changed like any other parameter. The I2CADDR pin (pin 1) should be left floating or connected to VCC to select the user-programmed address. The I²C standard reserves certain addresses, so recommended I²C addresses are 16 to 238 (0x10 to 0xEE hex).

Note that if there are multiple SM12xs on the same I²C bus there will be a collision before addresses can be changed. Therefore changing the address in this way may require a single-sensor programming setup.

Overriding the I²C Address with an External Jumper

Grounding the I²C address override pin ("I2CADDR"; pin 1) changes the I²C address to 16 dec regardless of the programmed address. Leaving the pin open or tied HIGH invokes the I²C address in nonvolatile memory, which is 72 dec by default but can be reprogrammed by the user in memory location 0x04. The pin is checked only on power-up.

Eight-Bit I²C Address

In accordance with industry standards, SM12x sensors have eight-bit I²C addresses (seven bits plus an R/W bit). Some I²C Master devices (such as Arduinos) send seven-bit addresses. In this case, the sensor address should be divided by two, so for example a default I²C address of 36 rather than 72 would be used.

Elegant Architecture

The SM12x uses a unique "Von Neumann" architecture where all data and parameters are written and read from memory. This eliminates the need for explicit commands. In addition, all data and coefficients are just one byte, which dramatically simplifies firmware, streamlines system development, and allows high-speed communication over a simple two-wire I²C interface.

Reading and Writing the Sensor Memory

Data is read by first writing an address byte to the sensor (with the I²C Read/Write bit set to "Write"). Subsequent I²C read commands will return the data or parameter in the active address. The address does not need to be re-sent before every read, so data can be read repetitively with only a single-byte read.

The default memory address is 0, which is the calibrated sensor output, so "out of the box" the sensor output can simply be retrieved with I²C read commands.

Reading from unsupported addresses will return 0xFF; writing to unsupported addresses has no effect.

Memory Map

	Symbol	De- fault	Read/ Write	Range	Address	Description
RAM (0x hex)						
Sensor (calibrated)	Sensor		R	0 – 255	0x00	Measured field as a percentage of linear range (100 = 1 mT for SM124 and 4 mT for the SM125).
Sensor (uncalibrated)	Sensor_Raw		R	–128 – 127	0x01	Raw bridge output, unsigned. Wraps on overflow.
Temperature	Temperature		R	–128 – 127	0x02	°C
Digital output	DOUT		R/W	0 – 1	0x03	Writing resets the output if latched
I ² C address	I2CADDR		R/W	16 to 238 (0x10 to 0xEE)	0x04	I2CADDR with pin 1 floating or HIGH
Factory setting restore			R	0 – 1	0x05	“1” restores factory settings
Nonvolatile Memory (2x hex)						
Default Mode Digital Output threshold, or lower threshold in window comparator mode	THRSH_L	100	R/W	1 – 255	0x20	% of linear range
Higher Digital Output threshold (window comparator mode only)	THRSH_H	255	R/W	1 – 255	0x21	255 if not used
Magnetic threshold differential	HYST	10	R/W	0 – 127	0x22	% of linear range; 255 invokes latching
Digital Output invert	DOUT_invert	0	R/W	0 – 1	0x23	HIGH to invert DOUT
Sensor offset	sensor_offset	0	R/W	–128 – 127	0x24	
Sensor sensitivity	sensor_sens	100	R/W	0 – 256	0x25	% of maximum
Temperature coef. of sensitivity	tempco	100	R/W	0 – 256	0x26	% of maximum
Temperature sensor offset	temp_offset	0	R/W	–128 – 127	0x27	°C
Temperature slope	temp_slope	100	R/W	0 – 256	0x28	Temp. calibration curve (%)
Digital filter constant	m	1	R/W	1 – 127	0x29	$f_{\text{CUTOFF}} = f_{\text{SAMPLE}} / (2\pi m)$; $f_{\text{SAMPLE}} = 10 \text{ kSps}$ $m = 1$ disables filter
I ² C pull-ups enabled		1	R/W	0 – 1	0x2A	1 = enable pull-ups (no pull-ups on Master); 0 = disable pull-ups (pull-ups on Master)
Magnet temperature compensation profile	magnet_comp	0	R/W	0 – 2	0x2B	0 = no compensation 1 = ceramic magnet 2 = NdFeB magnet
Read-Only Memory (8x hex)						
Lot code	YY	N/A	R	N/A (ASCII)	0x80–x81	ASCII date code in the form YYWWXX, where: YY = year; WW = work week; XX = internal code. The left-most character is in 0x80; right-most in 0x85.
	WW				0x82–x83	
	XX				0x84–x85	
Part type		N/A	R	ASCII	0x8A–0x8F	“SM124” or “SM125” (ASCII; 1 st character in 0x8A)

Table 2. SM12x memory addresses.

Power-Up and Initialization; What's Nonvolatile and What's Not

The above table is grouped into nonvolatile and nonvolatile.

All **parameters**, including Thresholds, Hysteresis, and Magnet Temperature Compensation, are nonvolatile so they can be set once via I²C, and then used without a microcontroller.

Measured and calculated **data** such as magnetic field and temperature are indeterminate until the first readings after power-up.

The default memory address is not preserved after power-down, and defaults to 0 (the calibrated magnetic field). The active address remains until it is changed, so multiple reads of the same address do not require writing the address before each read.

DOUT is not saved but initializes in the low field state. This ensures it will not be “latched” initially when used in the latching mode.

Digital Filter

The digital filter is an Infinite impulse response (IIR), weighted running average filter, where the filtered output is calculated as follows:

$$H_n = \frac{1}{m} H + \frac{m-1}{m} H_{n-1}$$

Where H = is the measured magnetic field; H_n = the filtered magnetic field; H_{n-1} is the previous value of the filtered magnetic field; and m is a constant that determines the cutoff frequency as described later.

The time-domain response is exponential, as shown below for a step change in magnetic field:

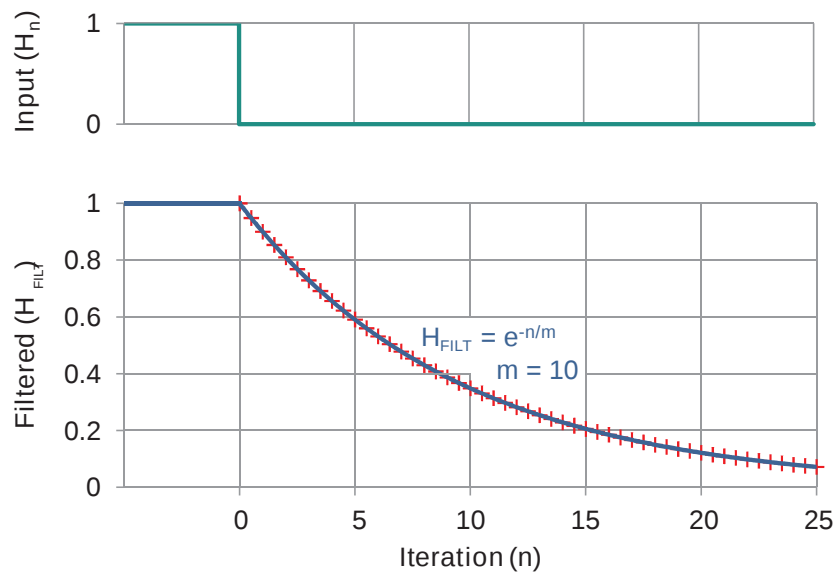


Figure 12. Digital filter time-domain response.

The filter provides a first-order response in the frequency domain:

$$f_{\text{CUTOFF}} = f_{\text{SAMPLE}} / (2\pi m)$$

Where f_{CUTOFF} is the filter cutoff frequency and f_{SAMPLE} is the sensor sampling rate (typically 10 kSps).

So for example, if $m = 16$, the cutoff frequency is approximately 200 Hz.

$m=0$ or $m=1$ disables filter so the output will simply be updated with each sample.

Application Circuits

Microcontroller Interface

A typical microcontroller interface is shown below:

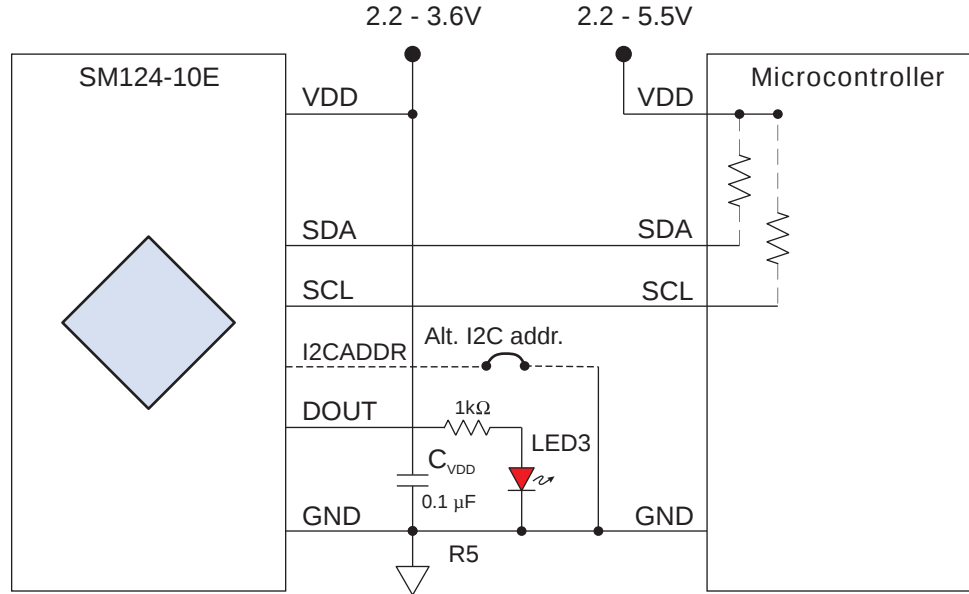


Figure 13. Typical microcontroller connections.

The SM12x is configured as a Slave and the microcontroller should be configured as the Master. The I²C interface is compatible with 3.3 or five-volt microcontrollers.

The SCL and SDA lines are open-drain, so the microcontroller's internal pull-up resistors should be activated in software. External resistors can be used to maximize rise time for high-speed I²C operation, or to preserve I²C speed if there are multiple slaves or a multi-master configuration adding bus capacitance. If external pull-ups are used with different power supplies, they should be connected to the lower supply voltage. A typical external pull-up resistor value is 10 kΩ. If I²C speed is not critical, the effects of bus capacitance can be overcome by slowing the I²C speed.

The I2CADDR pin can be left unconnected for the default I²C address (72 decimal/48 hex), or the pin can be ground to select an alternate address (16 decimal/10 hex).

V_{DD} should be bypassed with a 0.1μF capacitor placed as close as possible to the V_{DD} and GND pins.

An LED can be used to indicate the digital output. The appropriate series resistor depends on the supply voltage and LED type. A high-efficiency LED will operate over the sensor's entire 2.2 to 3.6V supply range with the 1 KΩ resistor, although its brightness will change with the supply voltage.

Overcurrent Protection

An SM12x digital output can be used as a “virtual circuit breaker” for overcurrent protection of a load such as a DC motor:

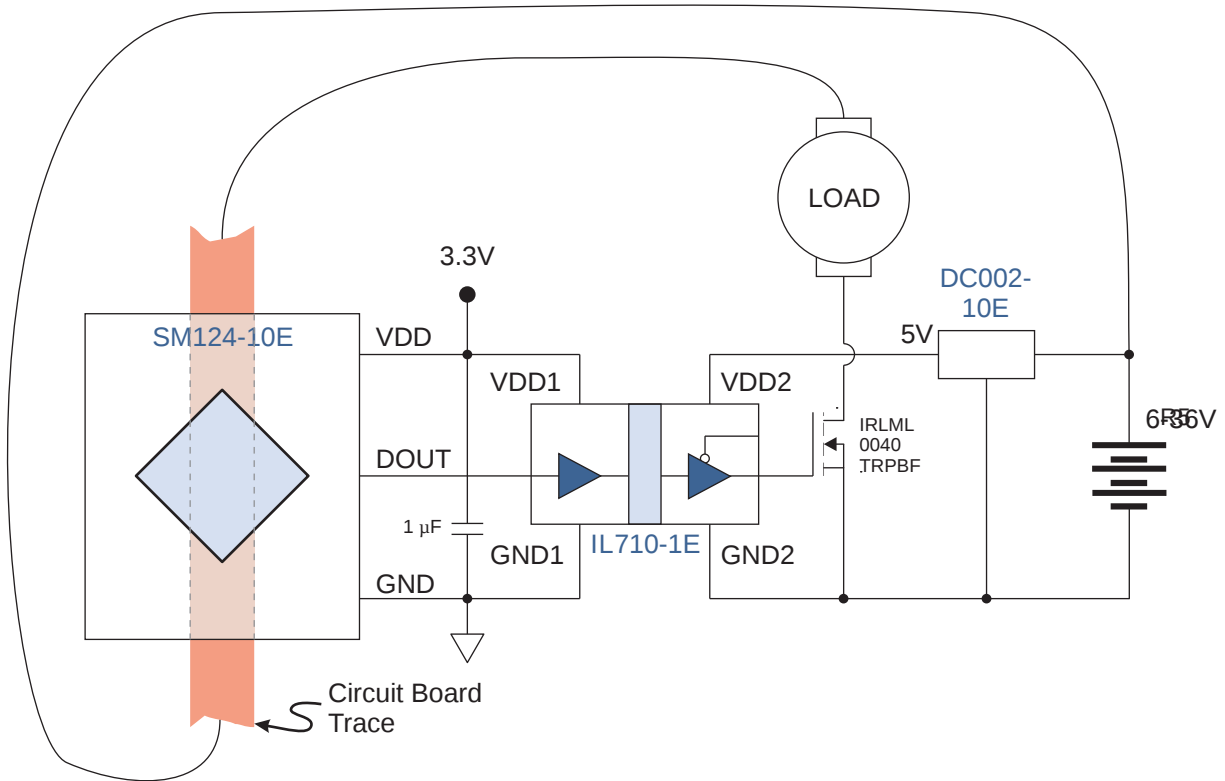


Figure 14. Typical overcurrent protection circuit.

The IL710-1E is an ultraminiature (MSOP8) data coupler that isolates the controller power from the load power. The DC002-10E is a high-voltage tolerant, five-volt regulator to power the gate drive. The power MOSFET has 4.5 volt drive voltage and 3.6 amp and 40 volt drain-to-source voltage capability. The sensor is located over a trace that carries current to the motor.

In this configuration, DOUT_invert is set to 1 to invert DOUT so that the output goes LOW for overcurrent. HYST and THRSH_H are set to 255 (dec) to invoke the latching mode where DOUT latches ON if the current exceeds the THRSH_L. The output can be reset by via I²C or by cycling the sensor power.

If the field generated by the motor current exceeds the threshold, DOUT goes LOW, the isolator output also goes LOW, the MOSFET turns off, and power is removed from the load.

The SM12x high sample rate ensures rapid detection of an overcurrent condition. But unlike shunt resistor-based circuits, there are virtually no losses associated with current sensing, and the controller can be electrically isolated from the motor for less noise and more safety.

An SM12x can also drive solid-state relays rather than the isolator and MOSFET in Figure 14. Relays are normally connected from DOUT to VDD to take advantage of the output’s high output sink capability. Relays with a three-volt “Must Turn On Voltage” and fairly high input impedance can be driven directly by the sensor output.

Reciprocating Actuator

A back-and-forth actuator can be constructed with just a single SM12x smart sensor, one magnet, and no microprocessor needed. The sensor's digital threshold output is connected to the direction input of a stepper motor driver board, so the actuator motor reverses as the sensor turns on and off:

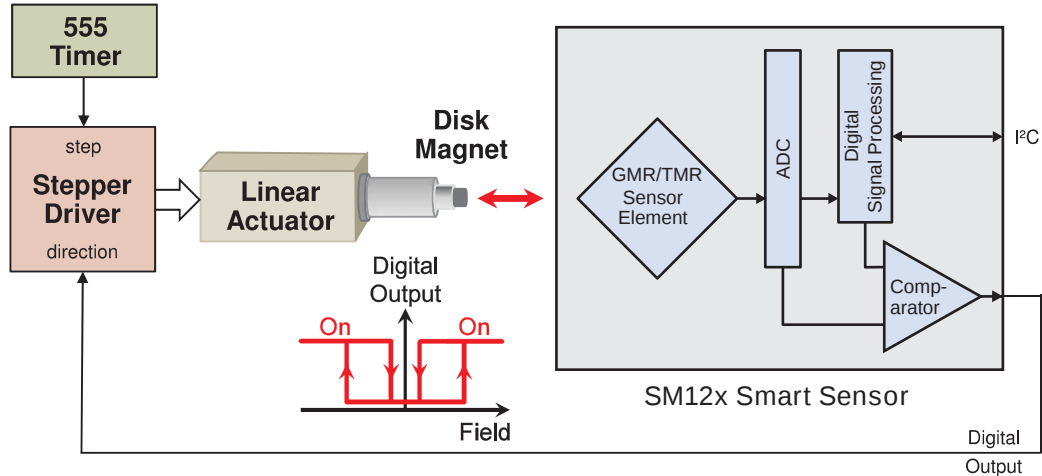


Figure 15. Reciprocating actuator using an SM12x smart sensor.

The flexibility and wide range of the sensor's digital threshold output makes it ideal for this application. For example, a 1 mT turn-on threshold with 0.9 mT hysteresis provides a 0.1 mT turn-off threshold and a distance of more than one inch (25 mm) between the turn-on and turn-off thresholds. Since the SM12x is omnipolar, it works with either magnet polarity.

The programmed thresholds are nonvolatile, so the sensor can be programmed once and then operated without a computer or microprocessor interface.

Illustrative Microcontroller Code

```

/*****
Reads an out-of the-box SM12x-10E Smart Position sensor with an Arduino Uno and outputs the
calibrated magnetic field to the serial port and an analog output.
I2C SDA on Arduino A4; SCL on A5; analog output on A9.
*****/

#include <Wire.h> //I2C library
int field; //Magnetic field (0-100 corresponds to 0-10 Oe)

void setup() {
  Serial.begin(9600); //Initialize serial communication at 9.6 kbps
  Wire.begin(); //Join I2C bus as Master
}

void loop() {
  Wire.requestFrom(36,1); //Request one byte from the SM12x (I2C addr. 72 shifted right 1 bit)

  field = Wire.read(); //Read sensor (data always valid so a "While" loop isn't needed)
  Serial.println(field); //Print on Arduino serial port
  analogWrite(9, field); //Send as analog output to pin 9

  delay(500); //Two samples per second
}

```

```

/*****
Sets an SM12x-10E threshold via an Arduino Uno. I2C SDA on A4; SCL on A5.
*****/
#include <Wire.h> //I2C Library
const unsigned char THRSH-L_address = 0x20; //Digital threshold in default mode
const unsigned char HYST_address = 0x22; //Magnetic threshold differential

const unsigned char THRSH-L = 100; //Threshold (100 = 10 0e)
const unsigned char HYST = 10; //Hysteresis (10 = 1 0e)

void setup() {
  Wire.begin(); //Join I2C bus as Master
  Wire.beginTransmission(36); //Transmit to I2C addr 72 shifted right 1 bit (SM12x default)
  Wire.write(THRSH-L_address); //Set Sensor active memory address to digital threshold
  Wire.write(THRSH-L); //Send threshold data
  Wire.write(HYST_address); //Set Sensor address to hysteresis
  Wire.write(HYST); //Send hysteresis data
  Wire.endTransmission();
  delay(15); //Allow parameters to be written to nonvolatile memory before proceeding}

void loop() {
}

```

Design Support

Breakout Boards

The AG958-07E breakout board for the SM124-10E and the AG961-07E breakout board for the SM125-10E provide easy connections to the sensor with a six pin connector. It also has the recommended 10 μ F bypass capacitor:

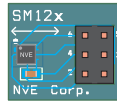


Figure 16. AG958-07 / AG961-07E breakout board
actual size; 0.5" x 0.6" (12 mm x 15 mm)

Evaluation Kits

This simple board includes an SM124-10E (AG952-07E board) or SM125-10E (AG962-07E board) Smart Magnetometer, a microcontroller that interfaces to the sensor via I²C, and interfaces to a PC via USB. The sensor can be activated with a magnet or an on-board current trace. A Windows-based user interface with single-click installation provides two-way communication with the sensor to display the sensor outputs and allowing field calibration:

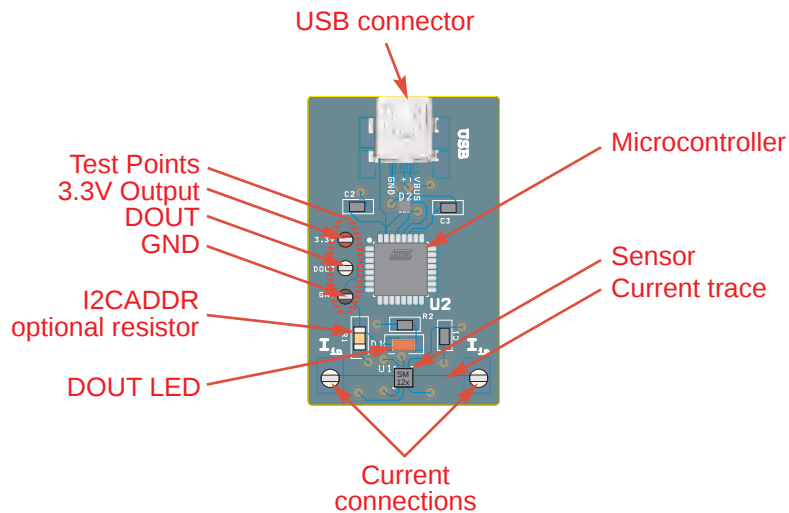


Figure 17. AG952-07E / AG962-07E SM12x Smart Sensor evaluation board
actual size; 1" x 1.625" (25 mm x 41 mm)

Socket Board

The AG954-07E provides connections to a TDFN6 socket for easy interface to smart sensors such as SM12x-10E without soldering:

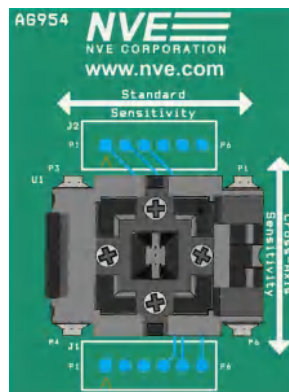


Figure 18. AG954-07E: TDFN socket board
(actual size) 1.5" x 2" (38 mm x 50 mm)

AG955-07E: Self-Contained Programmer

The AG955-07E is a self-contained programmer for SM12x sensors that allows zeroing the sensor and programming a simple digital output threshold and hysteresis without need of a computer or a customer microcontroller. The SM12x is connected to an I²C master microcontroller. Miniature rotary thumbwheel switches allow programming the threshold (THRSH_L) and hysteresis (HYST) as a percentage of sensor's the linear range. There is also a pushbutton for zeroing.

Jumpers allow the sensor to be disconnected from the rest of the board so the board can be used as an interface to the customer's electronics. The programmer can also connect to an AG958-07 or AG961-07E breakout board.

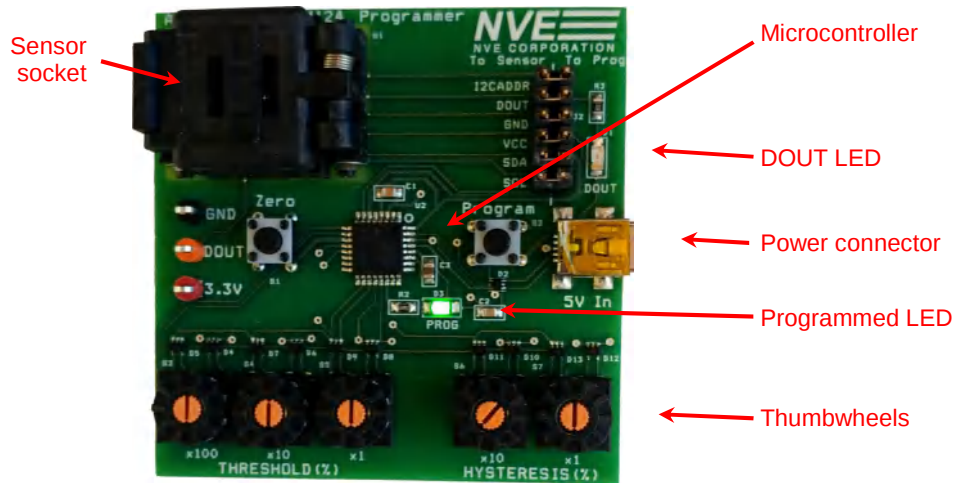
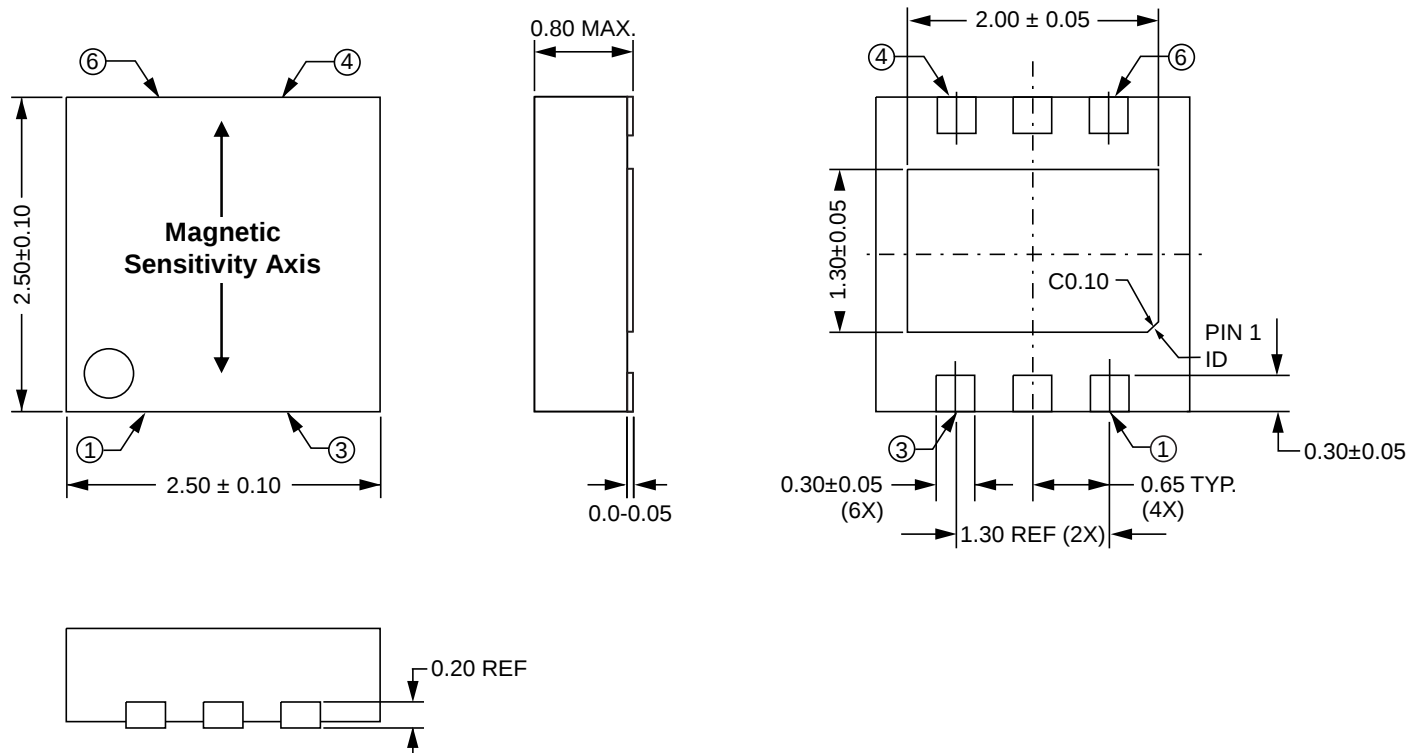


Figure 19. AG955-07E: Self-Contained SM12x Programmer (actual size)
2.5" x 2.5" (64 mm x 64 mm)

2.5 x 2.5 mm DFN6 Package



Pin	Symbol	Description
1	I2CADDR	I ² C address override (LOW-true input; read on power-up). Grounding this pin changes the I ² C address to 16 dec regardless of the programmed address. Open or HIGH invokes the I ² C address in nonvolatile memory.
2	DOUT	Digital Output (CMOS output; default HIGH if above threshold)
3	GND	V _{ss} /Ground
4	VCC	Power Supply (2.2 to 3.6V; bypass with 1 μF typ. capacitor)
5	SDA	I ² C Data (bidirectional; open drain)
6	SCL	I ² C Clock (input)
Center pad		Internal leadframe connection; connect to GND to minimize noise; leave unconnected for current-over-trace-sensing.

Notes:

- Dimensions in millimeters.
- Soldering profile per JEDEC J-STD-020C, MSL 1.

Ordering Information

SM12^x-10E - 10E TR^y

SM = Product Family (Smart Magnetometers)

1 = GMR_element with 1 byte data

2 = Magnetic Orientation (cross-axis, i.e., sensitive to a field vector in the pin 2 ⊥ pin 5 direction)

x = Magnetic field linear range

4 = 0 to 1 mT / 0 to 10 Oe

5 = 0 to 4 mT / 0 to 40 Oe

10 = Package (2.5 x 2.5 mm DFN6)

E = RoHS compliant (Pb-free)

y = Bulk Packaging Reel Size

TR7 = 7" Tape and Reel

TR13 = 13" Tape and Reel

Available Parts

Part	Linear Range	Package Marking
SM124-10E	1 mT (10 Oe)	CCBe
SM125-10E	4 mT (40 Oe)	CC1e

Revision History

SB-00-075-H December 2019	Change Added accuracy spec. for 3 to 4 mT range.
SB-00-075-G November 2019	Changes - Added high-field version (SM125). - Added Part Type in memory map for lot codes 1947xx and higher (p. 14). - Misc. minor changes.
SB-00-075-F September 2019	Changes - More specifics on bypass capacitors (p. 12). - Added bypass capacitor details to microcontroller application circuit. (p. 17). - Added second bypass capacitor to breakout board (p. 22).
SB-00-075-E August 2019	Changes - Added Absolute Maximum output current specification (p. 2). - Added RAM timing specifications (p. 3). - Corrected pin one location on Figure 1 (p. 5). - Added window comparator function effective for lot codes 1932xx and higher (p. 10). [refer to datasheet Rev. D for lot codes less than 1932xx]. - Changed nonvolatile memory addresses (p. 15). - Clarified lot code formatting and corrected its memory address range (p. 15). - Added reciprocating actuator application circuit (p. 20). - Changed Arduino code for new addressing (p. 21). - Replaced bare board with breakout board (p. 22).
SB-00-075-D April 2019	Changes - Allow programming the default I²C address (pp. 12, 14, and 22). - Corrected error in memory map addresses 28 to 2A.
SB-00-075-C April 2019	Change Recommended 1 μF rather than 0.1 μF bypass capacitor.
SB-00-075-B February 2019	Changes - Added details on center pad and grounding recommendation to minimize noise. - Added AG955-07E Self-Contained Programmer (p. 20). - Clarified direction of sensitivity (p. 25). - Minor typographic changes.
SB-00-075-A January 2019	Changes - Finalized memory addresses. - Added self-contained programmers and socket board to “Evaluation Support” section. - Minor typographic changes. - Release at Rev. A.
SB-00-075-Prototype December 2018	Changes - Updated specifications for prototype. - Deleted high-field version (SM125) pending product qualification.
SB-00-075-PRELIM-A September 2018	Change Updated specifications.

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