

1. TABLE OF CONTENTS

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|---|-----------|
| 1. TABLE OF CONTENTS | 1 |
| 2. GENERAL DESCRIPTION | 2 |
| 2.1 <i>Eval Kit Content</i> | 4 |
| 3. INTRODUCTION | 5 |
| 4. HARDWARE SET-UP | 6 |
| 4.1 <i>Connector CON01 – Sensor Adapter PCB and Control Box</i> | 6 |
| 4.2 <i>Connector CON02 – Analog and Digital Signals</i> | 8 |
| 4.3 <i>Schematics of the evaluation board</i> | 10 |
| 5. SOFTWARE | 12 |
| 5.1 <i>Graphical User Interface</i> | 13 |
| 5.1.1 <i>Measurement and Log File Location</i> | 15 |
| 5.2 <i>API</i> | 16 |
| 5.2.1 <i>Most Important API Methods</i> | 16 |

2. GENERAL DESCRIPTION

The SENIS® SEN3Dx Evaluation Kit is designed for evaluation of the real 3-axis magnetic field sensor which is a CMOS integrated device that allows the vectorial measurement of the three magnetic flux components Bx, By and Bz (Figure 1) in a field sensitive volume (FSV) of 100 x 100 x 10 μm³. The FSV is about 0.75 mm below the surface of the chip package. Please read the data sheet of SEN3Dx for details. In order to allow users to run and test sensors quickly, the kit consists of a board (PCB) with a SEN3Dx sensor mounted on it, a control box to communicate and configure, as well as the cable and power supply (Table 1). There is a green LED on the PCB to indicate if the sensor is powered.

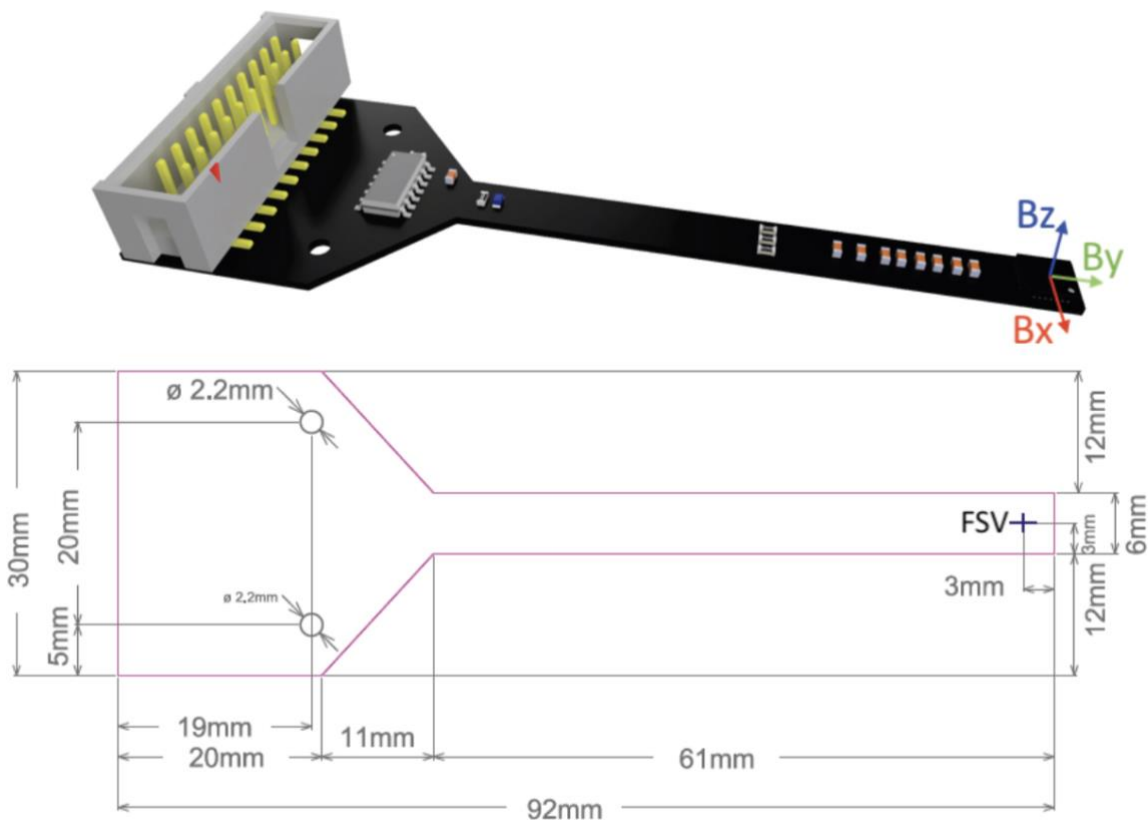


Figure 1: Top: Evaluation Kit PCB, with the coordinate system of the magnetic field vector. Bottom: Dimensions.

Since the SEN3Dx is still under development, the current version of the ASIC should be considered as a prototype with a set of limitations and functionality compromises. For instance, if the gain setting is changed, also data from the EEPROM, located at the respective position for the gain dependent settings, is loaded. This problem can be fixed by writing the correct or wanted values to the respective EEPROM addresses. Another issue is a rather high offset of the X channel at high gain values which reduces the useful measurement range in one direction.

Figure 2 shows the vertical position of the field sensitive volume (FSV). Note that these dimensions apply for the QFN-28 package with ceramic lid. The FSV is about 20 μm beneath the chip surface.

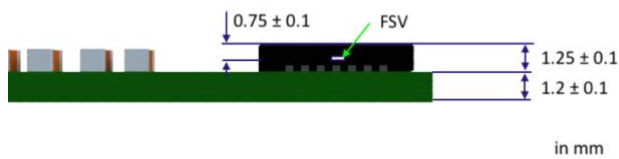


Figure 2: Vertical position of the field sensitive volume (FSV).

Important Note: It is recommended not to hot-plug (i.e. to connect the evaluation PCB if the control box is not powered off) the evaluation PCB to the control box with the Raspberry Pi (RasPi) embedded computer. So, please make sure the the RasPi is switched off (i.e. disconnect the device from power supply) and disconnect also the HDMI monitor cable, since the screen may deliver power to the sensor chip through the SPI interface and the digital power domain.

2.1 Eval Kit Content

Figure 3 shows the content of the evaluation kit. The item number labels correspond to the description in Table 1

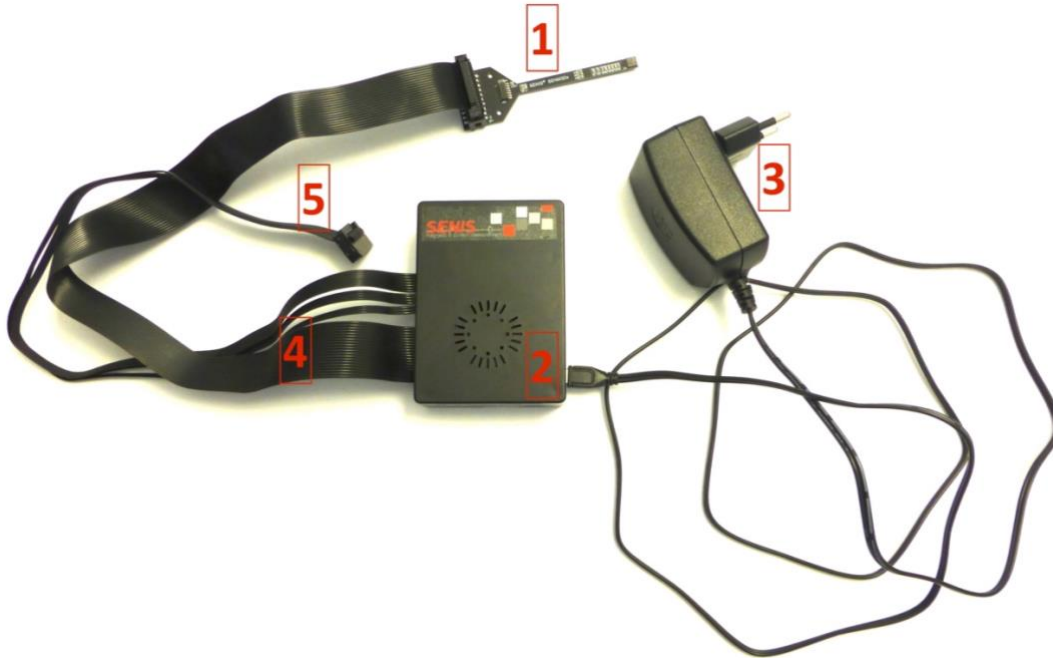


Figure 3: Evaluation kit content.

| Item No. | Item | Description |
|----------|----------------------------------|--|
| 1 | Evaluation PCB v1.1 | 1.2 mm thick FR4 PCB with SENM3Dx sensor mounted |
| 2 | Control Box | Includes RasPi 3B and provides SPI Interface, API and GUI |
| 3 | Power Supply¹ | 5V original Power Supply with microUSB connector |
| 4 | CON01 Connection Cable 01 | 20-way ribbon cable to connect the Control Box (2) to the Evaluation PCB v1.1 or v2.0 (1); IDC connector CON01 |
| 5 | CON02 Connection Cable 02 | 16-way ribbon cable to give access to the analog and digital outputs of the Evaluation PCB v1.1 or v2.0 (1); IDC connector CON02 |

Table 1: Evaluation Kit Content

Important Note: Convince yourself of the PCB version that you use and see the signal assignments shown in Table 2 to Table 5.

¹ The original power supply should be used to operate the evaluation kit. Otherwise, min. 5.1V output voltage and 2.5 A rated power supply needs to be connected.

Ref.No.: SENM3Dx EvalKit v1.0; AUG 2021

Rev.1.5

Page 4/20

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3. INTRODUCTION

The small printed circuit board (Evaluation PCB v1.1) is fully equipped with the SENM3Dx sensor and its necessary components for stable and reliable operation. All relevant signals are available on a 16 pin (2 x 8) IDC connector (Table 4; Figure 5). There is no need to install software to operate the sensor since the RasPI 3B provides the serial peripheral interface (SPI), advanced programming interface (API) and everything is pre-installed on the microSD card, including the operating system. The RasPI is the SPI master and controls the sensor chip.

Since SENM3Dx is equipped with an EEPROM, the user may write the most favorable settings to the sensor memory and operate the sensor without RasPI connected (an external power supply is needed in this case).

The analog outputs (XA, YA, ZA) deliver voltages proportional to the magnetic field and the analog output TA provides a voltage proportional to the chip temperature. These quantities are also available digitally via SPI interface. The three magnetic field components are also available as pulse-width modulated signals or comparator outputs.

4. HARDWARE SET-UP

4.1 Connector CON01 – Sensor Adapter PCB and Control Box

Note that there are two evaluation PCB versions on the market. Version 2.0 was introduced in JULY 2021. Please make sure that you check the label on the PCB in order to connect the correct signals. Do not mix the cables of different evaluation PCB versions.

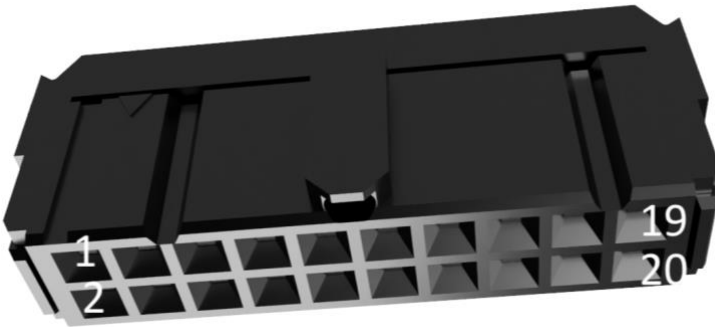


Figure 4: IDC connector CON01 head female, pitch 2.54 mm, 20 poles

| CON01 pin | Signal | Description |
|-----------|---------|---|
| 1 | VREF | Reference Voltage (+1.25 V); power |
| 2 | VCM | Virtual Ground (+2.25 V); output |
| 3 | GND | Ground (analog & digital) |
| 4 | AMUX | Analog Output ASIC Temperature |
| 5 | ZA | Analog Output Bz |
| 6 | XA | Analog Output Bx |
| 7 | YA | Analog Output By |
| 8 | VCC | Main Supply Voltage of the adapter PCB incl. SENM3Dx sensor(+5V); power |
| 9 | VCCA | Internal regulated analog supply voltage (4.5V); power |
| 10 | ZD | Digital Output Bz (PWM or comparator) |
| 11 | XD | Digital Output Bx (PWM or comparator) |
| 12 | YD | Digital Output By (PWM or comparator) |
| 13 | GND | GND; power |
| 14 | VDD | Internal Core Supply Voltage (+3.3 V); power |
| 15 | DMUX | For internal use only; do not connect |
| 16 | TEST_EN | For internal use only; do not connect |
| 17 | SSB | Chip (Slave) Select (active-low) |
| 18 | MISO | SPI Interface Master In Slave Out Signal |
| 19 | MOSI | SPI Interface Master Out Slave In Signal |
| 20 | MCLK | SPI Interface Clock Signal |

Table 2: IDC connector CON01 pin assignment for evaluation PCB version 1.1.

| CON01 pin | Signal | Description |
|-----------|---------|---|
| 1 | VREF | Reference Voltage (+1.25 V); power |
| 2 | VCM | Virtual Ground (+2.25 V); output |
| 3 | GND | Ground (analog & digital) |
| 4 | AMUX | Analog Output ASIC Temperature |
| 5 | ZA | Analog Output Bz |
| 6 | XA | Analog Output Bx |
| 7 | YA | Analog Output By |
| 8 | ZD | Digital Output Bz (PWM or comparator) |
| 9 | VCCA | Internal regulated analog supply voltage (4.5V); power |
| 10 | TEST_EN | For internal use only; do not connect |
| 11 | XD | Digital Output Bx (PWM or comparator) |
| 12 | YD | Digital Output By (PWM or comparator) |
| 13 | DMUX | For internal use only; do not connect |
| 14 | VDD | Internal Core Supply Voltage (+3.3 V); power |
| 15 | VCC | Main Supply Voltage of the adapter PCB incl. SENM3Dx sensor(+5V); power |
| 16 | GND | Ground (analog & digital) |
| 17 | MOSI | SPI Interface Master Out Slave In Signal |
| 18 | MISO | SPI Interface Master In Slave Out Signal |
| 19 | MCLK | SPI Interface Clock Signal |
| 20 | SSB | Chip (Slave) Select (active-low) |

Table 3: IDC connector CON01 pin assignment for *evaluation PCB version 2.0*.



4.2 Connector CON02 – Analog and Digital Signals

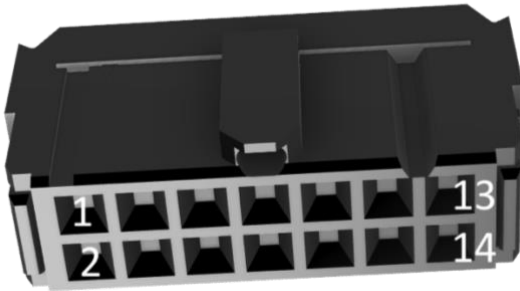


Figure 5: IDC connector CON02 head female, pitch 2.54 mm, 14 poles

| CON02 pin | Signal | Description |
|-----------|-----------|--|
| 1 | VREF | Reference Voltage (+1.25 V); power |
| 2 | VCM | Virtual Ground (+2.25 V); output |
| 3 | GND | Ground (analog & digital); power |
| 4 | AMUX | Analog Output ASIC Temperature TA |
| 5 | ZA | Analog Output Bz field component |
| 6 | XA | Analog Output Bx field component |
| 7 | YA | Analog Output By field component |
| 8 | VCCA | Internal regulated analog supply voltage (4.5V); power |
| 9 | ZD | Digital Output Bz (PWM or comparator) |
| 10 | XD | Digital Output Bx (PWM or comparator) |
| 11 | YD | Digital Output By (PWM or comparator) |
| 12 | VDD | Internal Core Supply Voltage (+3.3 V); power |
| 13 | TEST_DMUX | Digital Output; For internal use only; do not connect |
| 14 | TEST_EN | Digital Input; For internal use only; do not connect |

Table 4: IDC connector CON02 pin assignment for *evaluation PCB version 1.1*.



| CON02 pin | Signal | Description |
|-----------|-----------|--|
| 1 | VREF | Reference Voltage (+1.25 V); power |
| 2 | VCM | Virtual Ground (+2.25 V); output |
| 3 | GND | Ground (analog & digital); power |
| 4 | AMUX | Analog Output ASIC Temperature TA |
| 5 | ZA | Analog Output Bz field component |
| 6 | XA | Analog Output Bx field component |
| 7 | YA | Analog Output By field component |
| 8 | ZD | Digital Output Bz (PWM or comparator) |
| 9 | VCCA | Internal regulated analog supply voltage (4.5V); power |
| 10 | TEST_EN | Digital Input; For internal use only; do not connect |
| 11 | XD | Digital Output Bx (PWM or comparator) |
| 12 | YD | Digital Output By (PWM or comparator) |
| 13 | TEST_DMUX | Digital Output; For internal use only; do not connect |
| 14 | VDD | Internal Core Supply Voltage (+3.3 V); power |

Table 5: IDC connector CON02 pin assignment for *evaluation PCB version 2.0*.



4.3 Schematics of the evaluation board

Figure 6 shows the schematic of the evaluation PCB version 1.1 and Figure 7 version 2.0 respectively.

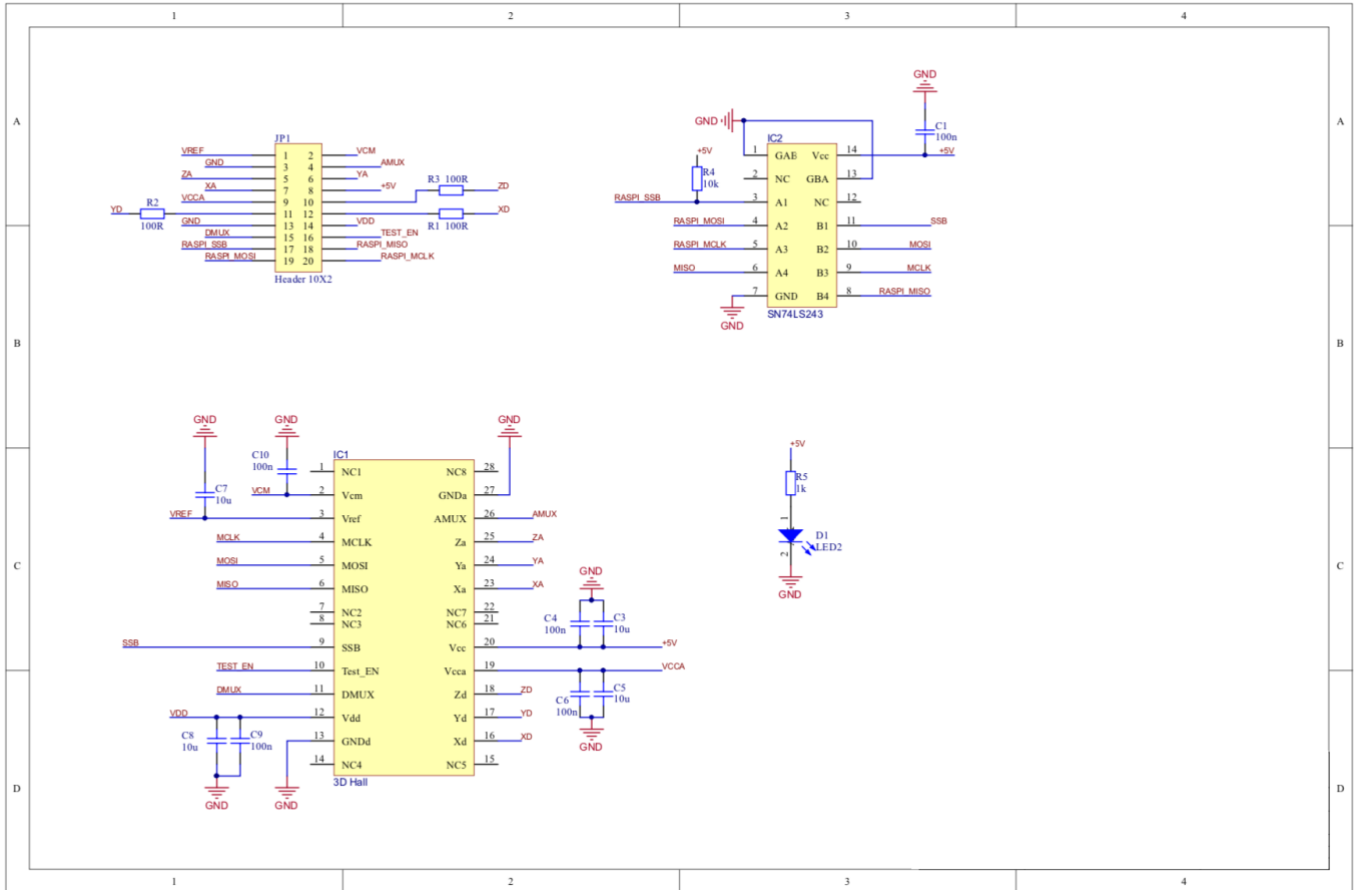


Figure 6: Schematic of the **evaluation PCB version 1.1**.

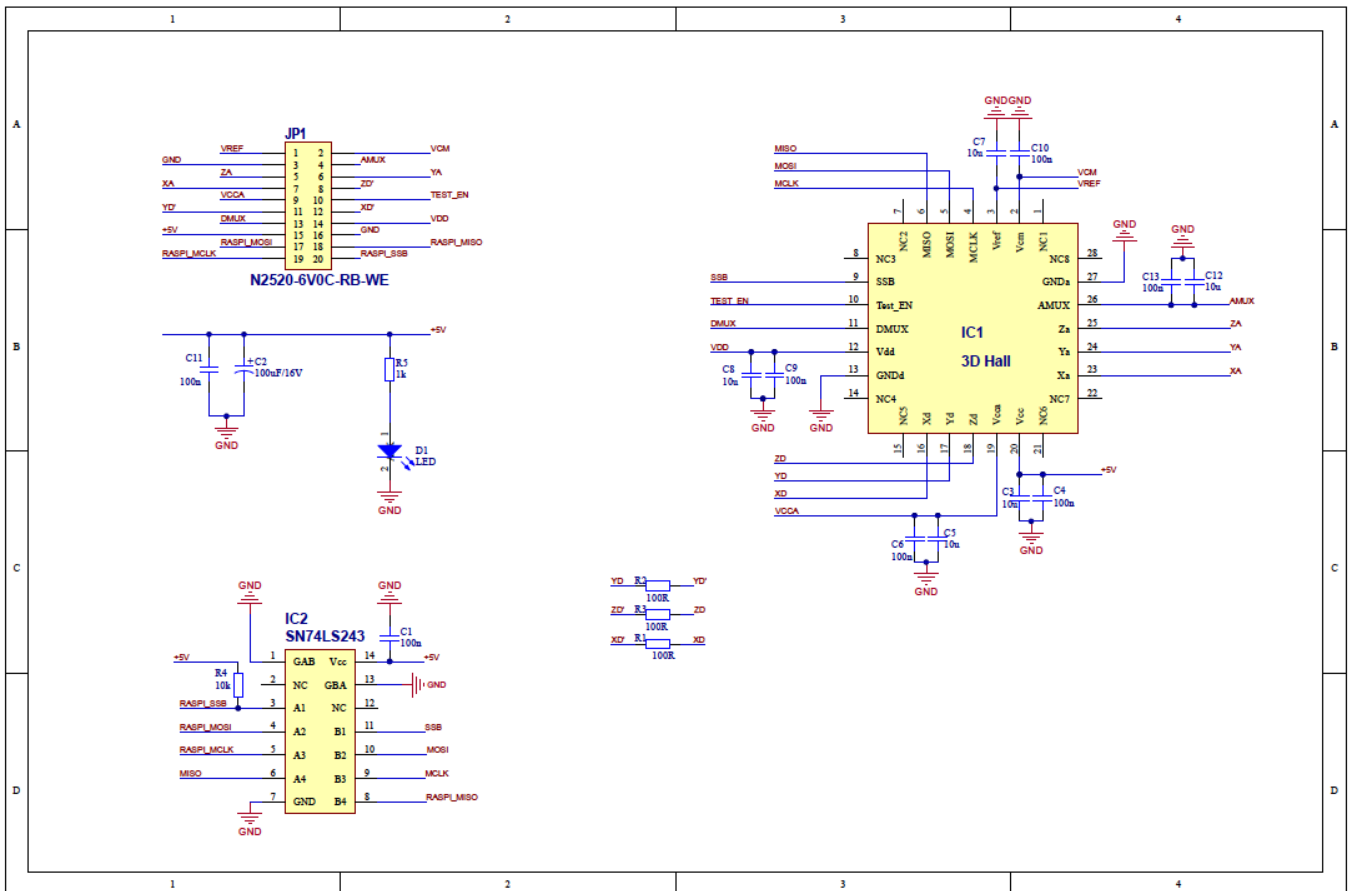


Figure 7: Schematic of the *evaluation PCB version 2.0*.



5. SOFTWARE

The RasPi is equipped with a 16 GB microSD card with all necessary software pre-installed and tested for Raspbian GNU/Linux version 10 (buster)² and python version 3.7.3³. Note that updates or upgrades of the system may cause compatibility issues and affect the functionality and/or performance of the software and libraries provided by SENIS.

Figure 8 shows the organization of the files which are essential for the communication with SENM3Dx located at `/home/pi/software/threeDhall_sw`.

```
|-- config
|   |-- calibration.cfg
|   `-- main.cfg
|-- init_interface.py
|-- ThreeDHallGUIv5p1.py
|-- ThreeDHALLInterface.py
`-- utilities
    |
    `-- utilities.py
```

Figure 8: Tree of SENIS software located at `/home/pi/software/threeDhall_sw`

² <https://www.raspberrypi.org/documentation/raspbian/>

³ <https://www.python.org/downloads/release/python-373/>

5.1 Graphical User Interface

The graphical user interface (GUI) is part of the pre-installed SENIS software and provides very basic functionality to read data from the SENM3Dx sensor and is organized in three tabs: Settings, Plot, Save.

The **Settings tab** (Figure 9) allows to control the measurement range (gain) selection for all channels (Bx, By, Bz), switching channels on and off, adjusting the offset of the Hall element directly (through adjusting the bias current) and verify the SPI interface. At any time, the current chip temperature and magnetic field reading is acquired from the sensor and displayed.

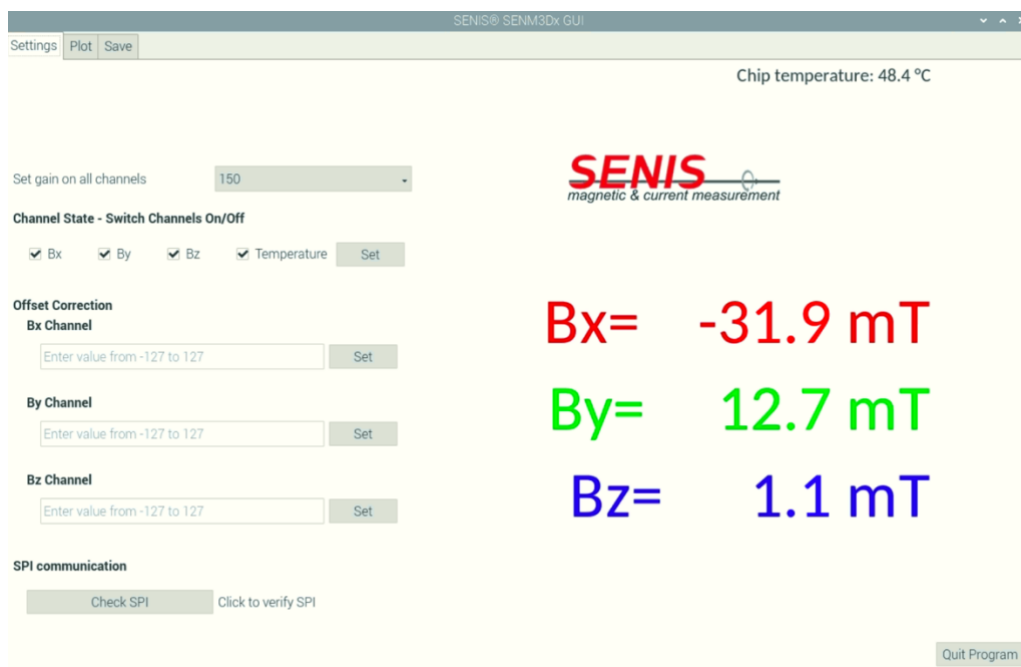


Figure 9: Image of the settings tab.

The **Plot tab** (Figure 10) allows the user to see the magnetic field reading over time. If the window is enlarged, it is a very convenient way of looking live at measurement signals.

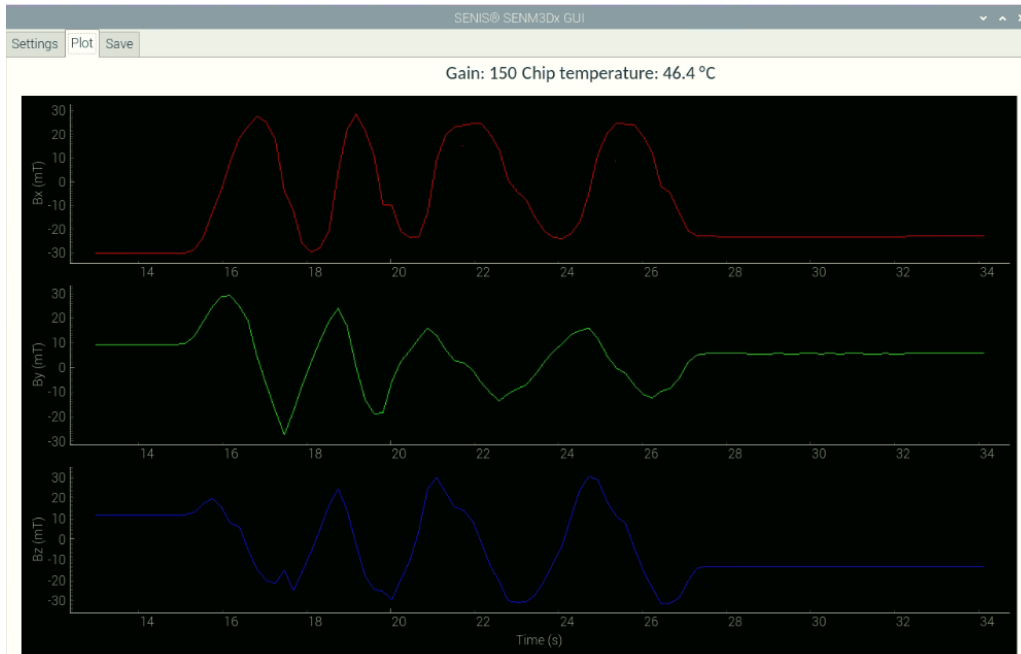


Figure 10: Image of the plot tab.

The **Save tab** (Figure 11) consists of:

- A text field to define the file path and name, which is also possible by clicking on the symbol next to it.
- Save and Stop buttons which allow to start and stop data saving on-the-fly.
- The save n number of samples button with a text field, which allows to save a certain number of data points.
- A plot area to show the sampled data, which is saved to a csv file.



Figure 11: Image of the save tab.



Figure 12 shows an example of a saved data file in csv format.

```

2020_03_16_10_26.csv x
1 Comment:
2 Gain: 150
3 Offsets
4 Bx axis: -100
5 By axis: -10
6 Bz axis: 20
7 Gain: 150
8 Offset correction values: Bx = -100, By= -10, Bz= 20
9 Time (s) ,Bx (mT) ,By (mT) ,Bz (mT) ,Temp (degC)
10 120.621 ,2.1 ,24.8 ,17.5 ,46.2
11 120.835 ,2.1 ,24.7 ,17.5 ,46.2
12 121.049 ,2.1 ,24.7 ,17.6 ,46.1
13 121.268 ,2.2 ,24.8 ,17.5 ,46.1
14 121.481 ,2.2 ,24.7 ,17.5 ,46.1
15 121.694 ,2.2 ,24.8 ,17.5 ,46.1
16 121.907 ,2.1 ,24.7 ,17.6 ,46.1
17 122.120 ,2.2 ,24.8 ,17.6 ,46.1
18 122.333 ,2.2 ,24.8 ,17.6 ,46.1
19 122.546 ,2.2 ,24.7 ,17.6 ,46.1
20 122.758 ,2.2 ,24.8 ,17.6 ,46.1
21 122.971 ,2.1 ,24.8 ,17.6 ,46.1
22 123.185 ,2.2 ,24.7 ,17.6 ,46.1
23 123.399 ,2.2 ,24.8 ,17.6 ,46.1
24 123.612 ,2.2 ,24.8 ,17.6 ,46.1
25 123.836 ,2.2 ,24.8 ,17.6 ,46.1
26 124.050 ,2.2 ,24.8 ,17.6 ,46.1
27 124.263 ,2.1 ,24.8 ,17.6 ,46.1
28 124.477 ,2.2 ,24.8 ,17.6 ,46.1
29 124.691 ,2.1 ,24.8 ,17.6 ,46.1
30

```

Figure 12: Image of a saved csv file.

5.1.1 Measurement and Log File Location

Measurement files are saved per default to the file location /home/pi/data/measurement_data/ and log files are saved to /home/pi/data/logs/ in time stamped folders.



5.2 API

Since the GUI supports only a very limited set of the SENM3Dx programming possibilities, the user gets access to the full sensor's functionality through the advanced programming interface (API). The API is implemented in Python as interface class in the file ThreeDHALLInterface.py.

Either use the link "Start 3DHALL Interface" on the desktop to run iPython3 and invoke the interface, or do it manually, i.e. open a shell and type: `cd /home/pi/software/threeDhall_sw && ipython3 -i init_interface.py` This will create an object "threeDhall_dev" of the interface class, and the user is ready to access all methods and class variables. The most important methods are listed alphabetically and are explained in the following section.

Looking at the `init_interface.py` file should give an idea how the user can just create his own Python file and insert code to perform certain tasks.

5.2.1 Most Important API Methods

Initialise the interface class to get access to the API:

```
threeDhall_dev = threeDhall.ThreeDHALLInterface()
```

The following methods are then accessible with the "dot" operator e.g.: `threeDhall_dev.closeSPI()`

Note that the utility methods, such as `write_bits_to_byte`, are not explained here. Often functions are shown with their default values for arguments e.g. `configureSPI(SPIMaxSpeedHz="7.8MHz")`.

activate_EEPROM_config()

The method writes the key and the actual checksum of the memory content to the EEPROM. After power cycle the sensor chip, the EEPROM data should be present in the respective registers.

change_channel_state(state=["on","on","on","on"], channel=["x","y","z","t"])

Set the Bx, By, Bz and Temperature channel to the respective state. All four channels have to be in the parameter list. Valid states are "on" and "off". Use `print_status()` to see the effect of the changes.

closeSPI()

Close the connection to the SPI interface of the RasPi.

configureSPI(SPIMaxSpeedHz="7.8MHz")

Set the SPI interface clock of the RasPi and mode (CPOL, CPH), data width, etc. according to the SENM3Dx interface definition. Valid clock speed parameters are: '7.6kHz', '15.2kHz', '30.5kHz', '61kHz', '122kHz', '244kHz', '488kHz', '976kHz', '1.9MHz', '3.9MHz', '7.8MHz', '15.6MHz', '31.2MHz', '62.5MHz', '125MHz'

Note that the recommended SPI clock setting is '7.8MHz' for stable operation especially with long (ribbon) cables.

deactivate_EEPROM_config()

Write 0x00 as key and a wrong checksum, so that data will not be loaded from EEPROM at power-up.



erase_EEPROM()

Write 0x00 to the entire EEPROM.

get_gain()

Returns the actual gain setting as integer value which corresponds to the measurement range.

get_temperature()

Returns the actual chip temperature in degC as float number.

openSPI(SPIBusID=0, SPIDeviceID=0)

Opens the SPI interface with default values SPIBusID=0 and SPIDeviceID=0, which corresponds to the wiring of the evaluation PCB. The RasPI would be able to handle two SPI devices (SPIDeviceID=1).

print_status()

Print out the actual state containing: Hall element bias currents, channel status, chip temperature, EEPROM key and checksum status, etc.

readSPI_clk()

Returns the current SPI clock setting as integer number.

read_EEPROM_check_sum_reg()

Returns the current value stored at address 0x1FF, where in case of EEPROM data loading active, the valid check sum is expected.

read_EEPROM_data(start_addr=0x00, num_bytes=1)

Read and return the number of bytes as list, beginning from start address in the EEPROM.

read_EEPROM_key_byte_reg()

Returns the current value stored at address 0x1FE, where in case of EEPROM data loading active, the valid key value 0xA5 is expected.

read_EEPROM_reg_val(reg_address=0x0A)

Read and return EEPROM data from a single address in the memory. Note that the EEPROM address offset is not used (e.g. EEPROM address 0x10A is equal to reg_address=0x0A).

read_adc_reg_data()

Returns a list of the four raw 16 bit ADC values of [Bx, By, Bz, Temperature].

read_b_field_values(num_of_samples=1, read_temperature=True)

Read and return a list of num_of_samples ADC values converted to magnetic field units mT. Note that the temperature value is always read and may be removed from the return value by setting the read_temperature parameter to False.

read_print_EEPROM_content()

The function reads, prints and returns the entire EEPROM content values from address 0x100 to 0x1FF as list.

read_reg(reg_address=0x09, num_of_bytes=1)

Basic read register read function which returns a list of num_of_bytes values from reg_address on. Note that also the three first zero bytes which are replied by the sensor are returned. So, if we perform for instance read_reg(reg_address=0x09, num_of_bytes=3), the function returns: [0, 0, 0, u, v, w], where u is the value at address 0x09, v of 0x0A and w of 0x0B.

read_reg_val(read_reg_val(reg_address=0x09))

Returns only the register value of reg_address.

select_digital_output(sel=["comp","comp","comp"], channel=["x","y","z"])

The output selection can be either the threshold/comparator output “comp” or “pwm” for each channel individually. Note that sel and channel has to be a list with three items each and only the key word “pwm” will cause the output to change from the comparator one. Use print_status() to see the effect of changes.

select_spinning_phases(phases=4)

Select either phases=2 or 4 to set the number of spinning phases. Use print_status() to see the effect of the changes.

set_amplifier_gain(data=150)

This function sets all three channels to the same gain. Accepted values for data=15, 150, 1500 and 3000 as integer which reflects the measurement ranges of 30 mT, 60 mT, 500 mT and 4 T.

verify_EEPROM_data_for_config()

Ref.No.: SENM3Dx EvalKit v1.0; AUG 2021

Rev.1.5

Page 19/20

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Returns “True” if the EEPROM content checksum is OK and the key is valid. “False” is returned otherwise.

verify_spi_interface(iterations=1000)

Data is written and read for iterations times and if it does match, “True” is returned. Otherwise the SPI interface has to be considered as corrupt, and “False” is returned.

write_EEPROM_reg(reg_address=0x10, data_to_write=0x00)

Write byte value as parameter data_to_write to EEPROM address at reg_address.
write_default_values_to_EEPROM

write_reg(reg_address=0x10, data_to_write=0x00)

Write byte value (data_to_write) to any register address (reg_address) from 0x00 to 0xFF. Note that all register write functions (in contrast to EEPROM access) are based on write_reg() and returns “True” if the write access was successful, “False” otherwise.