MICRONAS

Application
Note

HAL® 1002

User Manual

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APN000127_001EN

Contents

Release Note: Change bars indicate significant changes to the previous edition.

1. General Information

This document is intended as guidance for programming the HAL 1002 sensor using the HAL 1002 Programming Environment and an appropriate application kit (HAL Programmer V5.1). Every functionality integrated in the software is described and referenced to the corresponding functionality of the sensor. Additionally all calibration procedures implemented in the programming software are explained in detail. In combination with the data sheet and the application note “HAL 1002 Programming Guide” it represents the complete customer documentation of the HAL 1002.

1.1. Certification

TDK-Micronas GmbH fulfills the requirements of the international automotive standard ISO/TS 16949 and is certified according to ISO 9001:2000. This ISO standard is a worldwide accepted quality standard.

1.2. Support

We advise you to register on https://service.micronas.com in order to obtain access to the workgroups for our various product families. Here you are able to get support by opening support tickets in the customer support system. Additionally, once registered, you will receive notifications on software and Application Notes updates.

You are also able to contact the TDK-Micronas Support (product.support@micronas.com) in case of questions or problems.

TDK-Micronas GmbH - Application Engineering

Hans-Bunte-Strasse 19

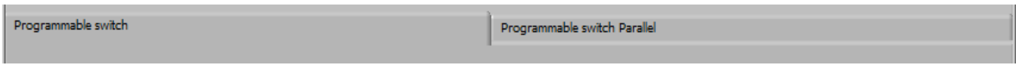
D-79108 Freiburg im Breisgau

E-mail: product.support@micronas.com

2. HAL 1002 Programming Environment

The HAL 1002 Programming Environment is a LabVIEW® application which needs a LabVIEW Run-Time Engine for execution. Each single functionality is also available as SubVI and can easily be modified or adapted to the individual requirements of a customer's application. The LabVIEW Run-Time Engines and the LabView SubVIs are also downloadable from https://service.micronas.com.

In addition to some controls and displays, the HAL 1002 Programming Environment application shows two tabs.



The **Programmable switch Tab** allows the user to read and change all programmable parameters, and to set the switching points for the selected sensor.

The **Programmable switch parallel Tab** allows the same functions for two sensors in parallel.

Detailed explanation of these tabs can be found in the following sections.

2.1. Running The Application

After a successful installation of the HAL 1002 Programming Environment the application can be started by clicking

START >> All Programs >> Micronas >> HAL 1002

When starting the application the window shown in Fig. 2–1 will appear. White fields indicate parameters which can be changed, grey fields are simple displays.

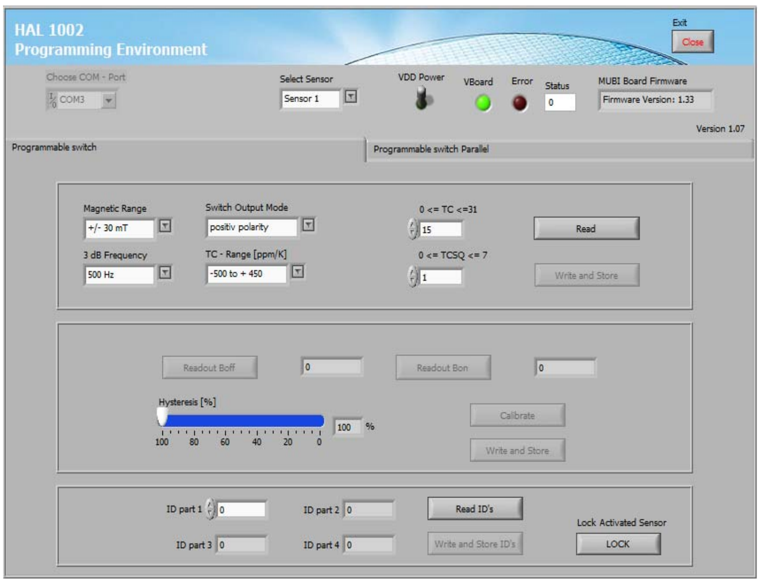


Fig. 2–1: HAL 1002 Programming Environment - Main Window

To run the application click on the white arrow in the menu bar (see Fig. 2–2, normally application is already running after starting). By clicking the red circle button the application will be stopped.

Fig. 2–2: Start / Stop execution

Communication Port

Once the application is running, as a first step the proper communication port connecting the PC to the Application has to be selected. A drop-down menu lists all available COM-Ports and offers a functionality to refresh the list, in case a new device has been plugged into the PC.

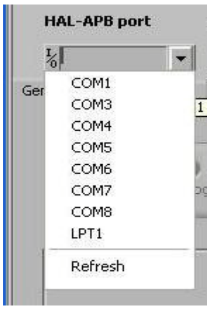


Fig. 2–3: COM port setting

The PC COM-Port can be figured out in the section Ports of the device manager, which can be launched by typing the command “devmgmt.msc” in the Windows2000/XP/Vista/7 command line as shown below.

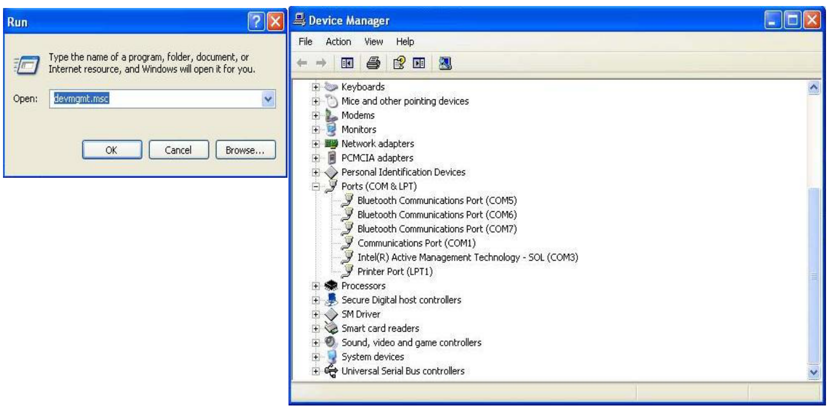


Fig. 2–4: Finding the correct COM port

Select Sensor

The user can program up to four sensors with the Application Board. This pull-down menu is enabled if the **Programmable switch Tab** is active. If the **Programmable Switch parallel tab** is selected the sensor selection control is disabled and the selection is done within the tab.

V_{DD} Power

The **V_{DD} Power** switch on the General Sheet must be switched to upper position to supply the HAL device connected to the Application Board.

VBoard LED

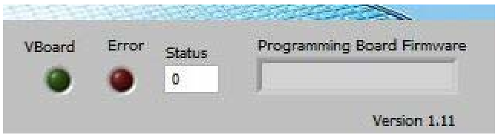
The VBoard LED indicates the $V_{SUP\ ON/OFF}$ status.

Error LED

The Error LED indicates if an error in communication between Application Board and sensor occurred.

Board Status & Firmware Version

In the Status display the feedback of the Programming Board is shown. The firmware of the Programming Board is read out after switching on VSUP and shows a working communication between the Programming Board and the software.



2.2. Description Of The Elements In The Programming Environment

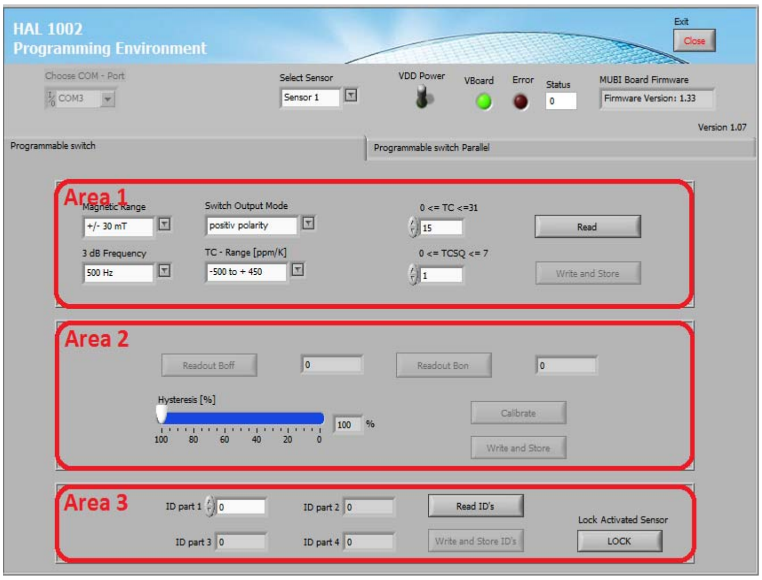


Fig. 2–5: HAL 1002 Programming Environment - Programmable switch tab

2.2.1. The Programmable Switch Tab

Area 1: General Sensor Settings

Output Mode Selection

Drop-down menu for the output mode selection.

The bits [7:5] of the MODE register define the two output modes of HAL 1002 (see Table 2–1).

Table 2–1: Output Modes Settings

Output Format	MODE [7:5]
positive polarity	100
negative polarity	101

Magnetic Range

Drop-down menu for the magnetic range selection (see Table 2–2).

Table 2–2: Magnetic Range Selection of the HAL 1002

Magnetic Range	RANGE	
	MODE [9]	MODE [2:1]
±15 mT	1	00
±30 mT	0	00
±60 mT	0	01
±80 mT	0	10
±100 mT	0	11
±150 mT	1	11

–3dB Filter Frequency

Drop-down menu for the –3dB filter frequency selection for the low pass filter.

Table 2–3: FILTER Bits Defining the –3dB Frequency

–3dB Frequency	MODE [4:3]
80 Hz	00
500 Hz	10
1 kHz	11
2 kHz	01

TC-Range

Drop-down menu for the temperature compensation pre-selection. With this drop-down menu the customer can switch between the four TC ranges.

Table 2–4: TC-Range Groups

TC-Range [ppm/k]	TC-Range Group
–3100 to –1800 **(not for ±15 mT range)**	0
–1750 to –550 **(not for ±15 mT range)**	2
–500 to +450	1
+450 to +1000	3

For each range it is possible to set TC and TCSQ values.

TCSQ

Quadratic temperature coefficient of the magnetic sensitivity. This register can be set with values between 0 and 7 in steps of 1 (3 bit).

TC

Linear temperature coefficient of the magnetic sensitivity. This register can be set with values between 0 and 31 in steps of 1 (5 bit).

Area 2: Switching Points Calibration

In this area the switching points of the HAL 1002 will be calibrated.

The procedure is described in the following:

1. Step
   - Click on the “Read” button to read-out the sensor parameters.
   - Change the parameters when necessary.
   - Click on the “Write and Store” button in Area 1 to save the changed parameter in the sensor.

Note: Step 1 is necessary for the initialization.

2. Step
   - Move the application to the first target switching point.
   - Click on the “Readout B_{OFF}” button.
   - Move the application to the second target switching point.
   - Click on the “Readout B_{ON}” button.
   - Click on the “Calibrate” button
   - Click on the “Write and Store” button in Area 2 to store the calculated calibrations parameters into the sensor.
3. Step
   - Lock the sensor by clicking the “LOCK” button in Area 3.

Warning: This register cannot be reset!

Area 3

Sensor Identification Numbers

The HAL 1002 family has 4 IDs. Only ID 1 is free-programmable for the customer and can be set with values between 0 and 8191 (13 bit register).

2.2.2. The Programmable Switch Parallel Tab

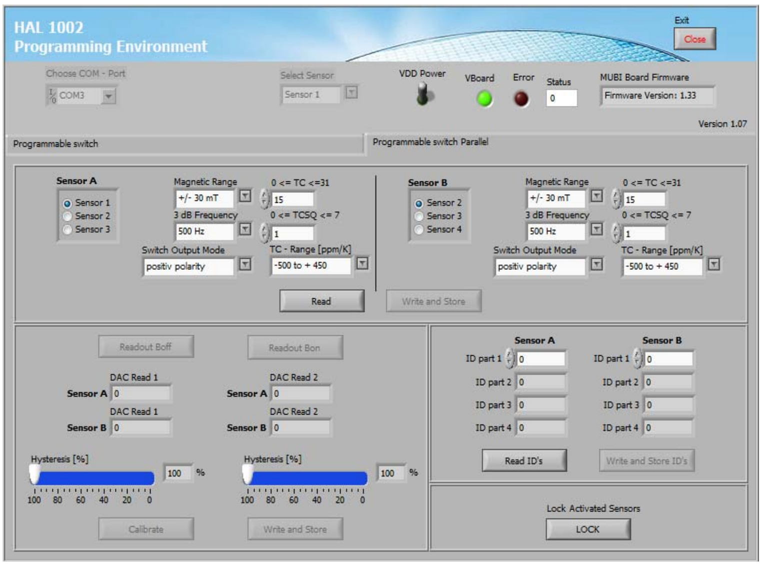


Fig. 2–6: HAL 1002 Programming Environment - Programmable switch Parallel tab

The **Programmable switch Parallel tab** (see Fig. 2–6) is used to perform a calibration of the switching points for two sensors in parallel.

The combination which of the 4 possible connectable sensors is freely selectable. The Select Sensor pull-down menu is disabled if this tab is active.

The procedure is the same as described in Section 2.2.1.

3. Switching Point Calibration

The diagrams in Fig. 3–7 and Fig. 3–8 show the possible switching behaviors which can be realized with the HAL1002. The upper diagrams of each of the four cases show the internal characteristic defined by the four scaling parameters SENSITIVITY, VOQ, LOW-LEVEL and HIGH LEVEL. SENSITIVITY and VOQ define the slope and the offset of the internal characteristic and the intersection of this characteristic with LOW-LEVEL and HIGH-LEVEL define at which magnetic field magnitude the output of the sensor switches from low level (typ. 0.2 V) to high level (typ. 4.8 V) or vice versa.

Note: The parameter HIGH-LEVEL and LOW-LEVEL are only internal parameters of the HAL1002. They don't define the output voltage level of the sensor.

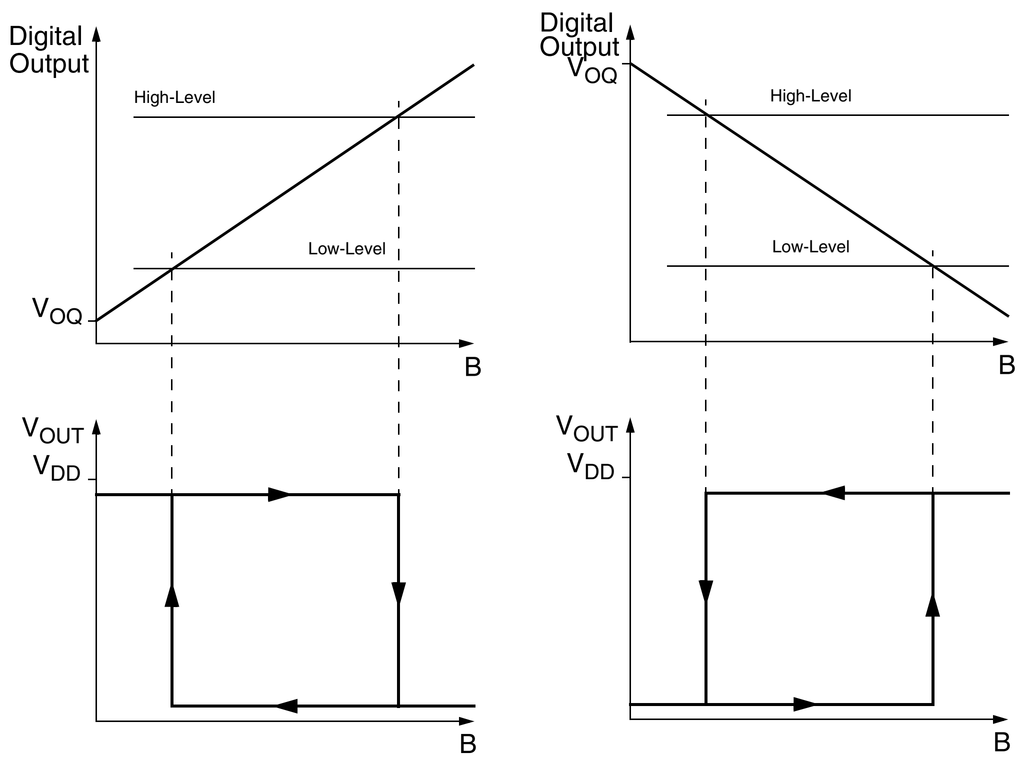


Fig. 3–7: HAL 1002 with unipolar (left side) and unipolar inverted behavior (right side); both south polarity

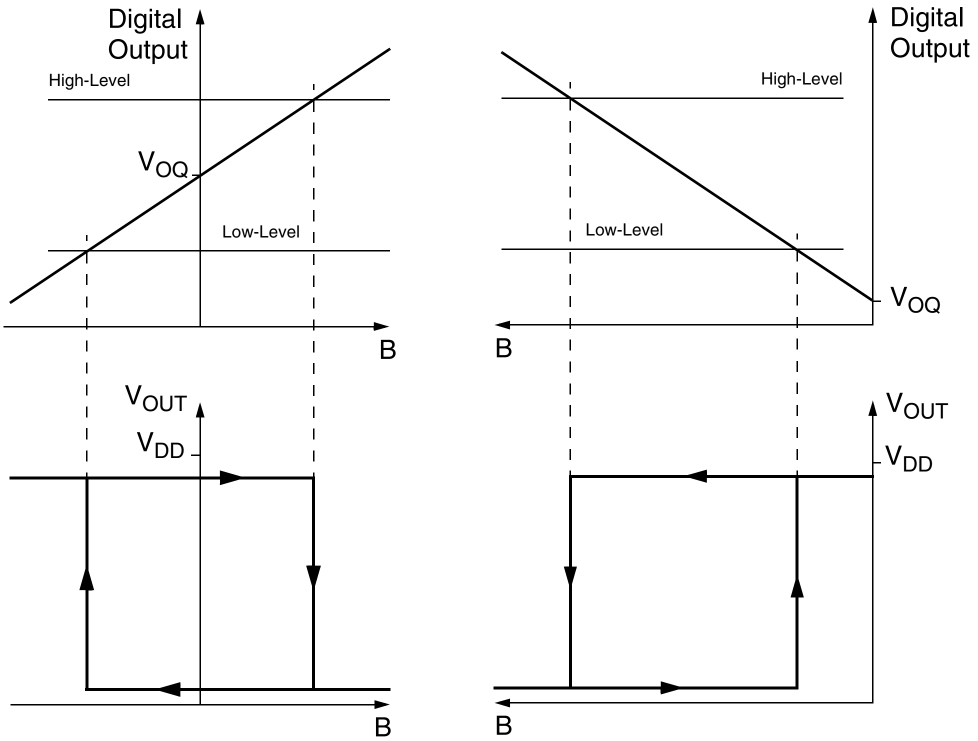


Fig. 3–8: HAL 1002 with latching (left side) and unipolar behavior to the north polarity (right side).

3.1. Calibration Procedure Details

For calibration in the system environment the application kit from TDK-Micronas is recommended. It contains the hardware to generate the serial telegram for programming (Programmer Board Version 5.1) and the corresponding software (HAL 1002 Programming Environment) for the input of the register values.

For the individual calibration of each sensor in the customer application, a two point adjustment is recommended. The calibration shall be done as follows:

Step 1: Input of the registers which do not require individual adjustment

The magnetic circuit, the magnetic material with its temperature characteristics, and the filter frequency are usually known for a given application.

Therefore, the values of the following registers shall be identical for all sensors in the given application.

- FILTER
  (according to the maximum signal frequency) The 500 Hz range is recommended for highest accuracy.
- RANGE
  (according to the maximum magnetic field at the sensor position)
- TC and TCSQ
  (depending on the material of the magnet and the other temperature dependencies of the application) Write the appropriate settings into the HAL 1002 registers.

Step 2: Initialize DSP

As the D/A-READOUT register value depends on the setting of SENSITIVITY, VOQ and HIGH/LOW LEVEL, these registers have to be initialized with defined values first:

- $VOQ_{INITIAL}$ = 2.5 V
- $Sens_{INITIAL}$ = (see Table 3–5)
- Low Level = 0 V
- High Level = 4.99 V

Table 3–5: Values for $Sens_{INITIAL}$

–3 dB filter frequency	$Sens_{INITIAL}$
80 Hz	0.464
500 Hz	0.3
1000 Hz	0.321
2000 Hz	0.641

Note: This step is done by the software automatically by clicking the Write and Store button in Area 1.

Step 3: Calculation of the Scaling Parameters

Fig. 3–9 shows the typical characteristics for a contactless switch. There is a mechanical range where the sensor must be switched high and where the sensor must be switched low.

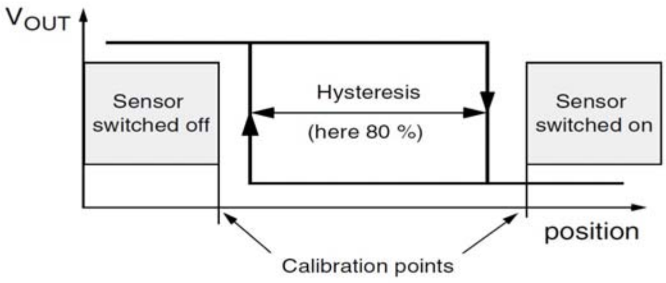


Fig. 3–9: Characteristics of a position switch

Set the system to the calibration point where the sensor output must be high, and click “Readout B_{OFF}”. The result is the corresponding D/A-READOUT value.

Note: The magnetic south pole on the branded side generates negative D/A-READOUT values, the north polarity positive values.

Then, set the system to the calibration point where the sensor output must be low, click “Readout B_{ON}” and get the second D/A-READOUT value.

Now, adjust the hysteresis to the desired value. The hysteresis is the difference between the switching points and suppresses oscillation of the output signal. With 100% hysteresis, the sensor will switch low and high exactly at the calibration points. A lower value will adjust the switching points closer together. Fig. 3–9 shows an example with 80% hysteresis.

With these values the target values for Sensitivity, Voq, Low Level and High Level are calculated:

The values for Target1 and Target2 are set to 0.5 V and 4.5 V.

$$\text{Sensitivity} = \text{Sensitivity}_{\text{INITIAL}} \times \frac{(\text{Target2} - \text{Target1})}{(\text{D/A-Readout2} - \text{D/A-Readout1})} \times \frac{16384}{5}$$

$$\text{Voq} = \text{Target2} - \left[\left(\frac{5 \times \text{D/A-Readout2}}{16384} - \text{Voq}_{\text{INITIAL}}\right) \times \frac{\text{Sensitivity}}{\text{Sensitivity}_{\text{INITIAL}}}\right]$$

By clicking the buttons "Calibrate" and "Write and Store" in Area 2 the software calculates the corresponding parameters for Sensitivity, VOQ, LOW LEVEL, HIGH LEVEL and stores these values in the EEPROM.

This calibration must be done individually for each sensor.

The sensor is now calibrated for the customer application. However, the programming can be changed if necessary as long as the sensor is not locked.

Step 4: Locking the Sensor

The last step is activating the LOCK function by programming the LOCK bit. Please note that the LOCK function becomes effective after a power-on reset (power-down and power-up of the Hall IC). The sensor is now locked and does not respond to any programming or reading commands.

Warning: The Lock register cannot be reset!

3.2. Pseudo Source Code For The Calibration

```
//Initialization
int Calc_D/A-Readout1, Calc_D/A-Readout2 = 0; /* D/A-Readouts used in the calculation */
double sens = 0, voqINI = 2.5, Target1 = 0.5, Target2 = 4.5;

//Insert integer data for D/A-Readout1 and D/A-Readout2 @calibration points
int D/A-Readout1 = 0;/* integer data for D/A-Readout1 */
int D/A-Readout2 = 0;/* integer data for D/A-Readout2 */

//Insert double data for sensINI – depending on the initialized 3dB filter frequency
double sensINI = 0; /* double data for sensINI */
//sensINI:
//80 Hz → 0.464
//500 Hz → 0.3
//1000 Hz → 0.321
//2000 Hz → 0.641

//Insert string for Output mode
OUTPUT_MODE
Calc_OUTPUT_MODE

if ((D/A-Readout1<8192 && D/A-Readout2<8192) || (D/A-Readout1>8192) && (D/A-Readout2>8192)) {
        if (D/A-Readout1 > 8192) {
                if (D/A-Readout1 > D/A-Readout2) {
                        Calc_D/A-Readout1 = D/A-Readout1;
                        Calc_D/A-Readout2 = D/A-Readout2;
                }
                else {
                        Calc_D/A-Readout2 = D/A-Readout1;
                        Calc_D/A-Readout1 = D/A-Readout2;
                }
                if (OUTPUT_MODE = "positive_polarity") {
                Calc_OUTPUT_MODE = "negative_polarity";
                }
                else {
                Calc_OUTPUT_MODE = "positive_polarity";
                }
        }
        else {
                if (D/A-Readout1 > D/A-Readout2) {
                        Calc_D/A-Readout2 = D/A-Readout1;
                        Calc_D/A-Readout1 = D/A-Readout2;
                }
                else {
                        Calc_D/A-Readout1 = D/A-Readout1;
                        Calc_D/A-Readout2 = D/A-Readout2;
                }
        }
}
else {
        Calc_D/A-Readout1 = D/A-Readout1;
        Calc_D/A-Readout2 = D/A-Readout2;
}
```

```
sens = ((Target2 - Target1) * 16384 * sensINI) / ((Calc_D/A-Readout2 – Calc_D/A-Readout1) * 5);
voq = Target2 – ((5 * Calc_D/A-Readout2 / 16384) – voqINI) * sens / sensINI);

while ((sens < -3)||(sens > 3)||(voq < -4.5)||(voq > 4.5)) {
        Target1 = Target1 + 0.001;
        Target2 = Target2 - 0.001;

        sens = ((Target2 - Target1) * 16384 * sensINI) / ((Calc_D/A-Readout2 – Calc_D/A-Readout1) * 5);
voq = Target2 + (sens * 5 * (Calc_D/A-Readout2 - 8192)) / (sensINI * 16384);
}

//If Hysteresis < 100 %

LowLevel = ((Target2 - Target1) / 2) + Target1 – ((Target2 - Target1) * Hyst / 100 / 2);

    HighLevel = ((Target2 - Target1) / 2) + Target1 + ((Target2 - Target1) * Hyst / 100 / 2);
```

4. Memory Map

Table 4–6: Available register addresses

Register	Code	Data Bits	Format	Customer	Remark
LOW-LEVEL[1)]	1	8	binary	read/write/program	Low Level voltage
HIGH-LEVEL[1)]	2	9	binary	read/write/program	High Level voltage
VOQ[1)]	3	11	two's compl. binary	read/write/program	Output quiescent voltage
SENSITIVITY[1)]	4	14	signed binary	read/write/program	
MODE	5	10	binary	read/write/program	Range, filter, output mode, Offset Correction settings
LOCKR	6	2	binary	read/write/program	Lock Bit
A/D READOUT	7	14	two's compl. binary	read	
GP REGISTERS 1..3	8	3x13	binary	read/write/program	[2)]
D/A-READOUT	9	14	binary	read	Bit sequence is reversed during read
TC	11	10	binary	read/write/program	bits 0 to 2 TCSQ bits 3 to 7 TC bits 8 to 9 TC Range
GP REGISTER 0	12	13	binary	read/write/program	[2)]
DEACTIVATE	15	12	binary	write	Deactivate the sensor

[1)] Only internal (scaling) parameters

[2)] To read/write this register it is mandatory to read/write all GP register one after the other starting with GP0. In case of writing the registers it is necessary to first write all registers followed by one store sequence at the end. Even if only GP0 has to be changed all other GP registers must first be read and the read out data must be written again to these registers.

Table 4–7: Data formats

Register	Char	DAT3				DAT2				DAT1				DAT0			
	Bit	**15**	**14**	**13**	**12**	**11**	**10**	**09**	**08**	**07**	**06**	**05**	**04**	**03**	**02**	**01**	**00**
LOW-LEVEL	Write	–	–	–	–	–	–	–	–	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	–	–	–	–	–	–
HIGH-LEVEL	Write	–	–	–	–	–	–	–	V	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	V	–	–	–	–	–
VOQ	Write	–	–	–	–	–	V	V	V	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	V	V	V	–	–	–
SENSITIVITY	Write	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V	V
MODE	Write	–	–	–	–	–	–	V	V	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	V	V	–	–	–	–
LOCKR	Write	–	–	–	–	–	–	–	–	–	–	–	–	–	–	V	V
	Read	–	–	V	V	–	–	–	–	–	–	–	–	–	–	–	–
A/D READOUT	Read	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V	V
GP 1..3 Registers	Write	–	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V	–
D/A-READOUT[1)]	Read	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V	V
TC	Write	–	–	–	–	–	–	V	V	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	V	V	–	–	–	–
GP 0 Register	Write	–	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V
	Read	–	–	V	V	V	V	V	V	V	V	V	V	V	V	V	–
DEACTIVATE	Write	–	–	–	–	1	0	0	0	0	0	0	0	1	1	1	1

V: valid, –: ignore, bit order: MSB first

[1)] LSB first

5. The Programming Procedure

5.1. Programming Procedure

In this section the general programming procedure for the HAL 1002 using the HAL Programmer V5.1 is described in detail.

An example of a programming procedure is given in Fig. 5–10.

First, the programmer board has to be initialized. If more than one sensor is connected to the same supply line, the sensors have to be addressed sequentially. This is done by the multiprogramming loop. After deactivating all sensors, the sensor to be programmed is activated again by sending a pulse on the corresponding output line, followed by a dummy read command.

Note: The flow chart given in Fig. 5–10 is intended as a simple example. The multiprogramming loop can also be done within the calibration procedure.

Please keep in mind that the board commands “e...”, “q...”, “m...”, and “t” cause the board to send back an eight character string to the PC. This string must be read out of the serial port before sending the next command.

Example:

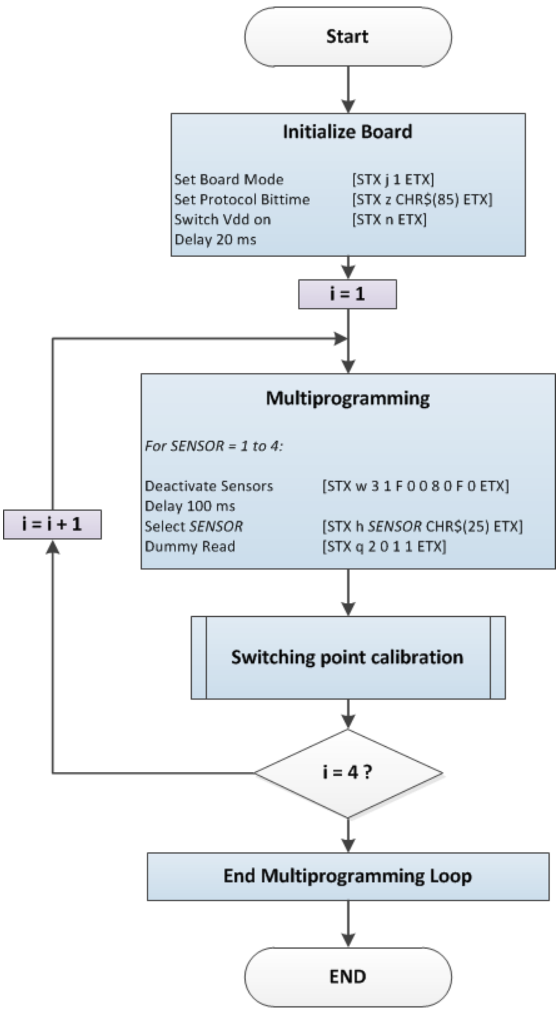


Fig. 5–10: General programming procedure

5.2. Switching Point Calibration Procedure

The calibration procedure flow including the board commands is shown in Fig. 5–11. The register values are intended as an example:

Step 1:

Programming of the parameters which do not require individual adjustment:

– Filter Frequency, Magnetic Range, Output Mode, TC (TC, TCSQ and TC-Range) and GP.

Step 2:

Initialize DSP

As the D/A-READOUT register value depends on the settings of SENSITIVITY, VOQ, LOW LEVEL and HIGH LEVEL, these registers have to be initialized with defined values, first.

Step 3:

Get the D/A-Readout value for the first calibration point.

Step 4:

Get the D/A-Readout value for the second calibration point.

Step 5:

Calculate and program the values of SENSITIVITY, VOQ, LOW LEVEL and HIGH LEVEL.

Step 6:

Store the registers permanently.

The “Store” sequence is given in Fig. 5–12. The permanent storing of data into the EEPROM memory is a two-step process. First, all zero bits (ERASE), then all one bits (PROM) are written.

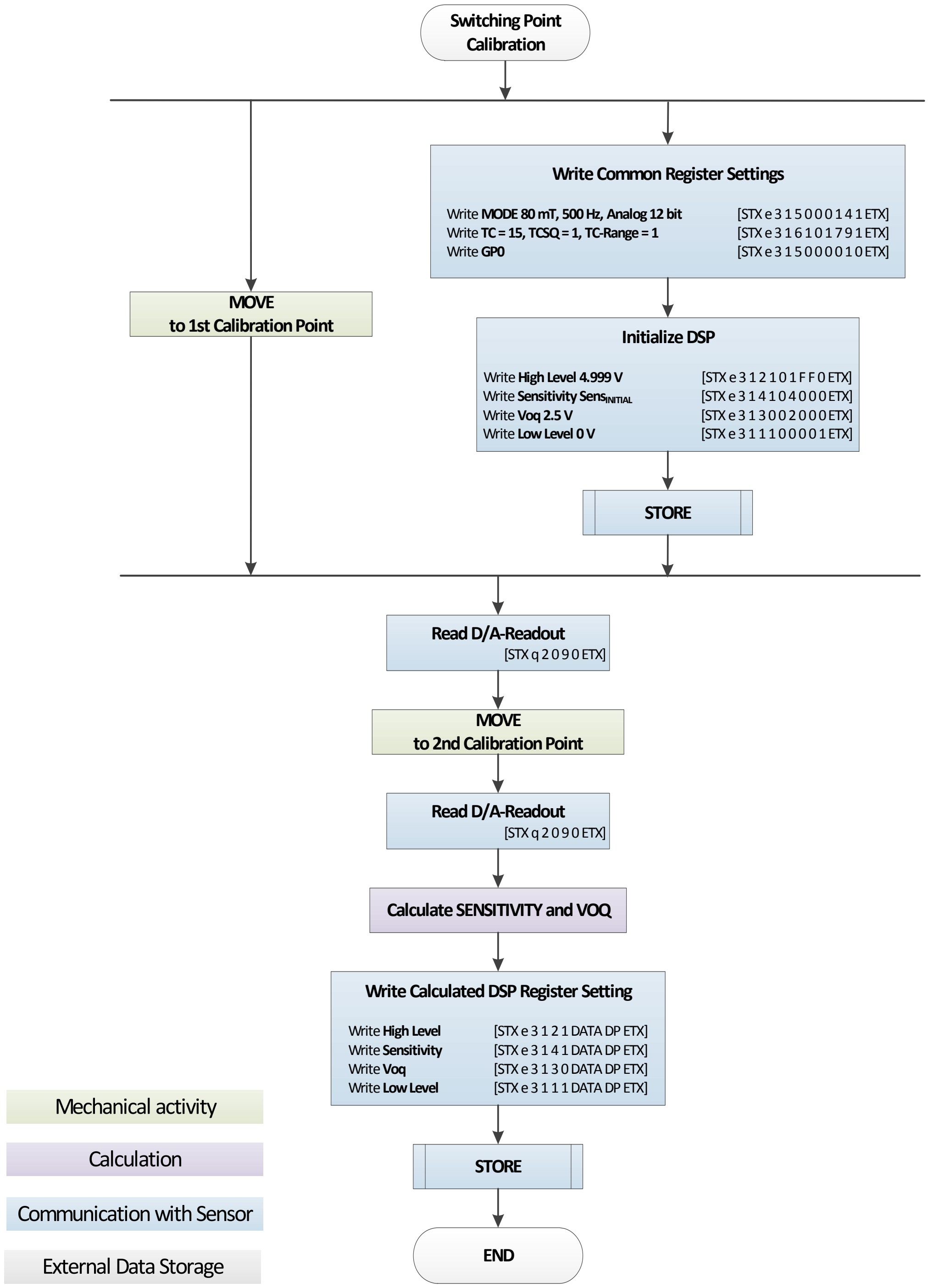


Fig. 5–11: Switching Point Calibration

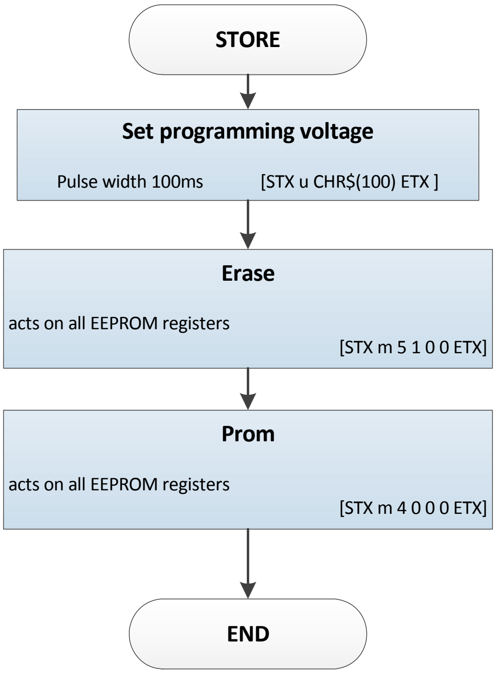


Fig. 5–12: Store sequence

5.3. Check Of Lock Function

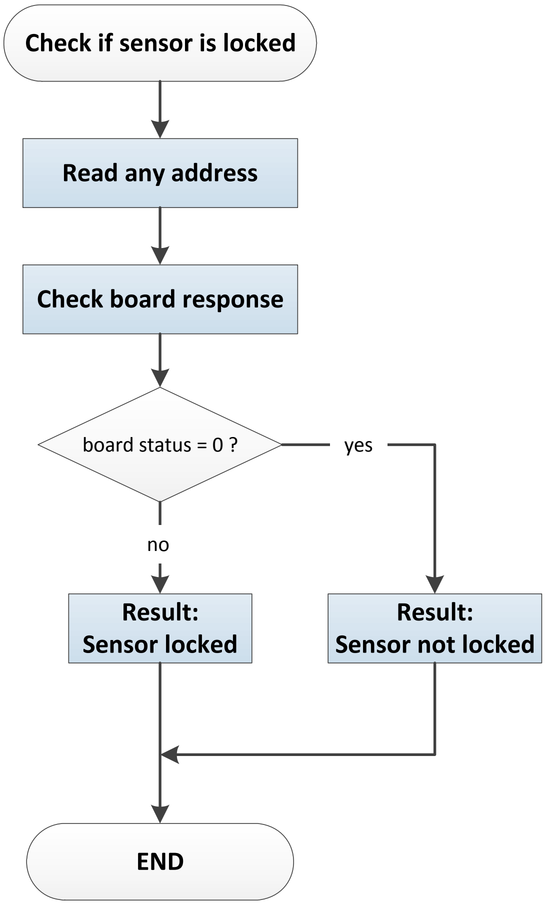


Fig. 5–13: Lock function

6. Application Note History

1. HAL 1002 Programming Guide, Jan. 20, 2014; APN000094_001EN. First release of the application note.
2. HAL 1002 Programming Guide, March. 6, 2018; APN000094_002EN. Second release of the application note.

   Changes:

   - Programmable switch parallel tab in the software added

Note: The document has been converted into two separate documents due to internal formalities. New Documents:
APN000127_001EN HAL 1002 User Manual
APN000128_001EN HAL 1002 Programming Guide.

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1. HAL 1002 User Manual, March. 6, 2018; APN000127_001EN. First release of the application note.

   Major Changes:

   - Section 1 (General Information) added
   - Section 1.2 (Support) updated
   - Section 2 (Installation) removed
   - New Section 2 (HAL 1002 Programming Environment) updated
   - Section 3 (Calibration) added
   - Section 3.1 (Calibration Procedure Details) updated
     – Step 2: Initialize DSP added
     – Formula for Sensitivity and V_{OQ} added
   - Section 3.2 (Pseudo Source Code For The Calibration) added
   - Parameter A/D Readout added to Table 4–6 and Table 4–7 added
   - Section 5 (Programming HAL 1002 Sensor With Own Software) removed
   - New Section 5 (The Programming Procedure) added