SDH – Joint positioning calibration

1. Overview

This document describes the joint positioning calibration process of the SDH. The 7 joints of the SDH are each equipped with 2 systems for position measurement:

- An absolute angle encoder
- An incremental angle encoder

The absolute encoder is needed to determine the absolute position of a joint at start without the need for an explicit reference movement of the joint at each power up. The incremental encoder provides the higher resolution needed for precise movement control.

1.1. Absolute angle encoder

The absolute angle encoders use a diametrically magnetized (two-pole) magnet for position measurement. The sensor is mounted at the output end of the gear box. It uses a resolution of 10 bit for a full 360° turn. Therefore the sensor can measure the absolute position of the joint with a precision of at most

- all joints: $360°/2^{10}$ = 0.352° only.

1.2. Incremental angle encoder

The incremental angle encoder is integrated directly into the motor and is thus mounted to the input end of the gear box. It uses a resolution of 512 encoders per turn which yields a total of 4*512=2048 encoder ticks per turn by using the quadrature encoding. Therefore the sensor can measure the incremental position of the joint with a precision of at most 360°/(4*512*gear_ratio). This yields a precision of:

- root joint, (gear_ratio = 1:357.75): 0.0005°
- proximal joint, (gear_ratio = 1:150): 0.0012°
- distal joint, (gear_ratio = 1:190): 0.0009°

2. Calibration of the absolute encoders

Unfortunately the magnets used for the absolute angle encoders cannot be mounted precisely in a definite way. Therefore their orientation must be “learned” once for every joint and stored in a non-volatile memory. The procedure for this is called the calibration of the absolute encoders and is usually performed by SCHUNK before an SDH is shipped to the customer. Nonetheless it might be necessary for the customer to repeat the calibration procedure, e.g. after a firmware update or after parts of an SDH have been replaced or repaired.

2.1. Preparation

2.1.1. Setup

To perform the calibration process you need the following:

- A PC with an RS232 interface (native or via adapter, e.g. USB to RS232)
- An SDH connected to the PC by RS232
- An RS232 terminal program on the PC

- for Windows the „`HyperTerminal`“ will do the job,
- for Linux „`minicom`“ is one of many RS232 capable terminal programs
- On request SCHUNK can provide a Python based terminal program „`mini-term.py`“ that works for Windows as well as for Linux.

The Windows HyperTerminal is provided by Microsoft, see `Programs`→ `Accesso-ries`→ `Communication`→`HyperTerminal` or the like. The `minicom` program is provided via the normal package update mechanism for most Linux distributions.
The terminal program must be configured to use the following communication parameters:

- Baudrate: 115200 Bit/s
- Data-Bits: 8
- Parity: None
- Stop-Bits: 1
- Flow control: None
- Terminal emulation: VT100
- Local echo: On
- Line ending: Send CR, LF as line ending

2.1.2. Configuring HyperTerminal

As an example the configuration of the Windows `HyperTerminal` program is shown in the figures Figure 1 to Figure 6. The screenshots are taken from a German version of the program.

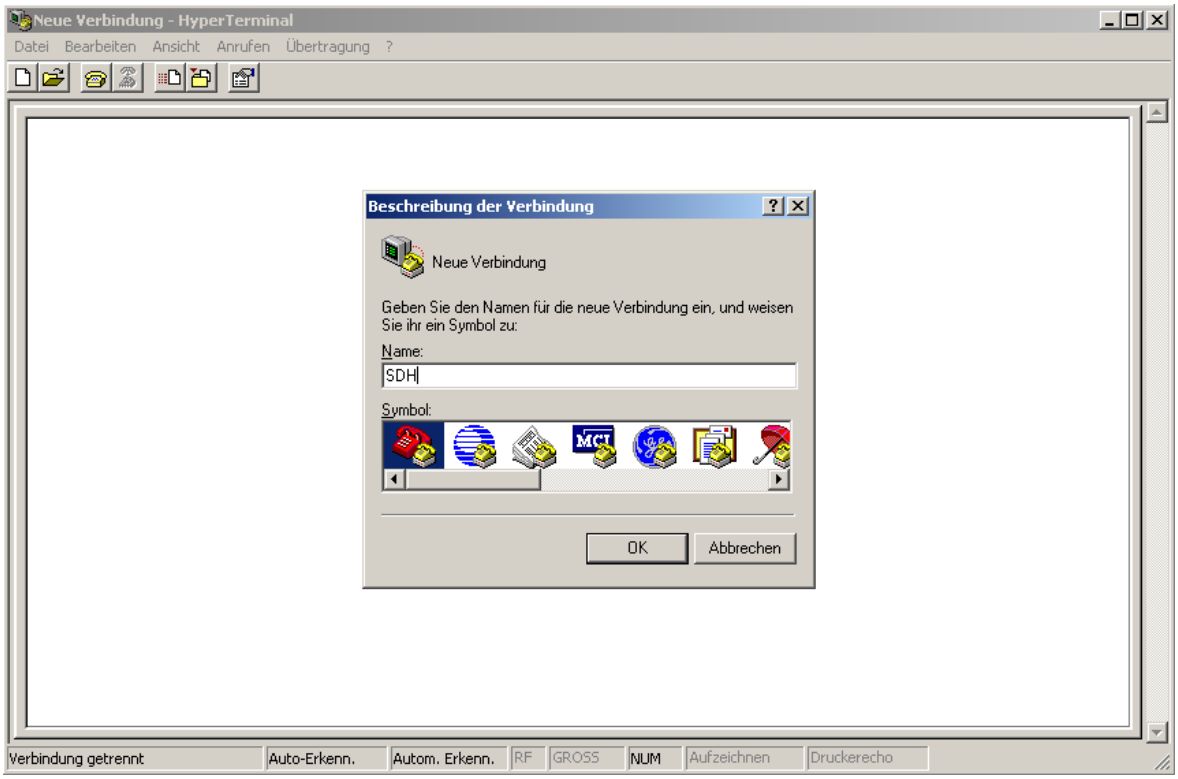

Figure 1: Start screen of HyperTerminal, enter a name like „SDH“ for the new connection and press OK.

Figure 2: Select the RS232 interface that connects to the SDH. Here „COM1“ was selected, then press OK

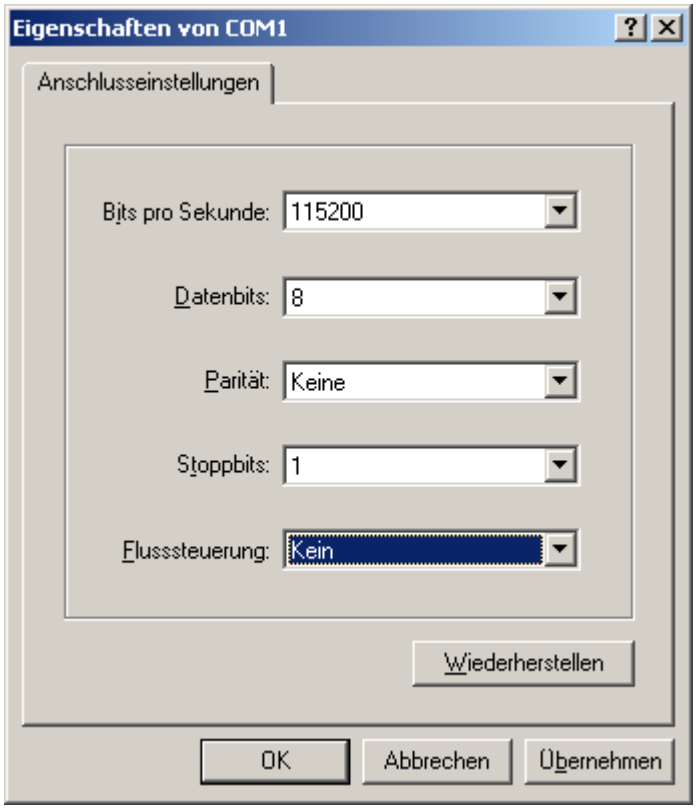

Figure 3: Define the communication parameters: Baudrate: 115200 Bits per second; 8 Data bits; No parity; 1 Stop bit; no Flow control. Then press OK.

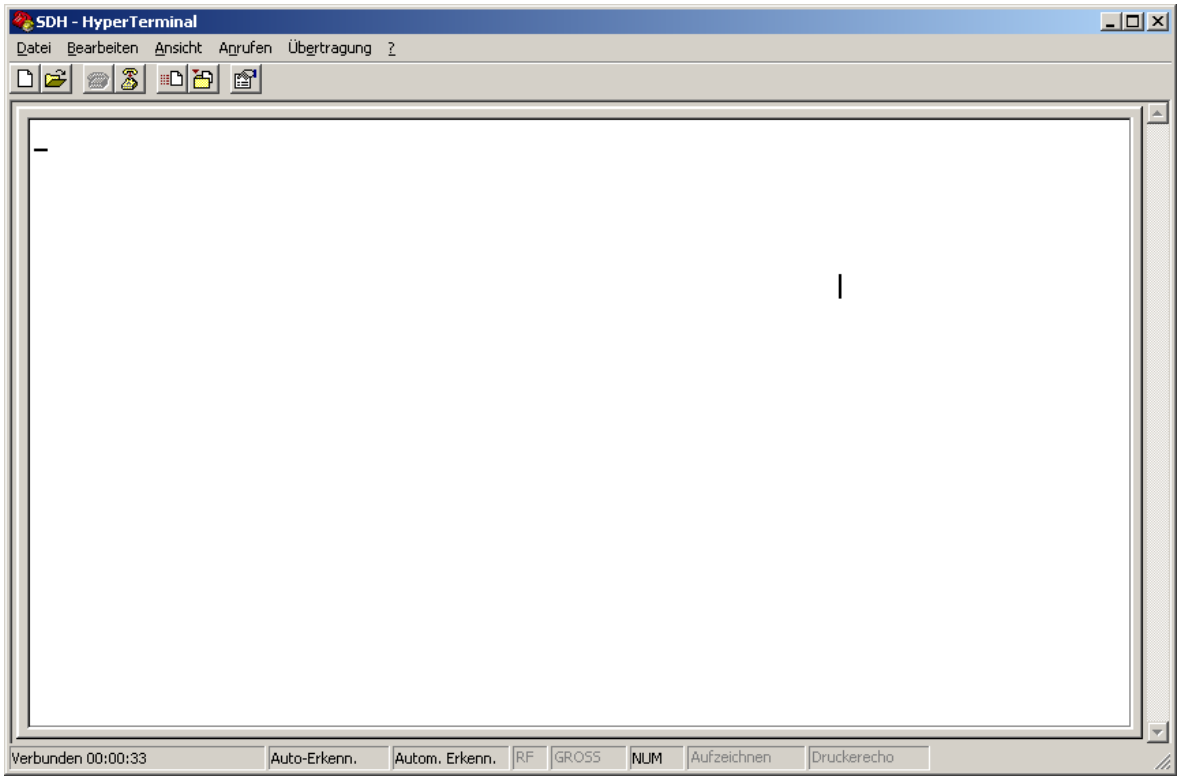

Figure 4: The program has connected and listens for incoming data. You can later send data by typing in the white area.

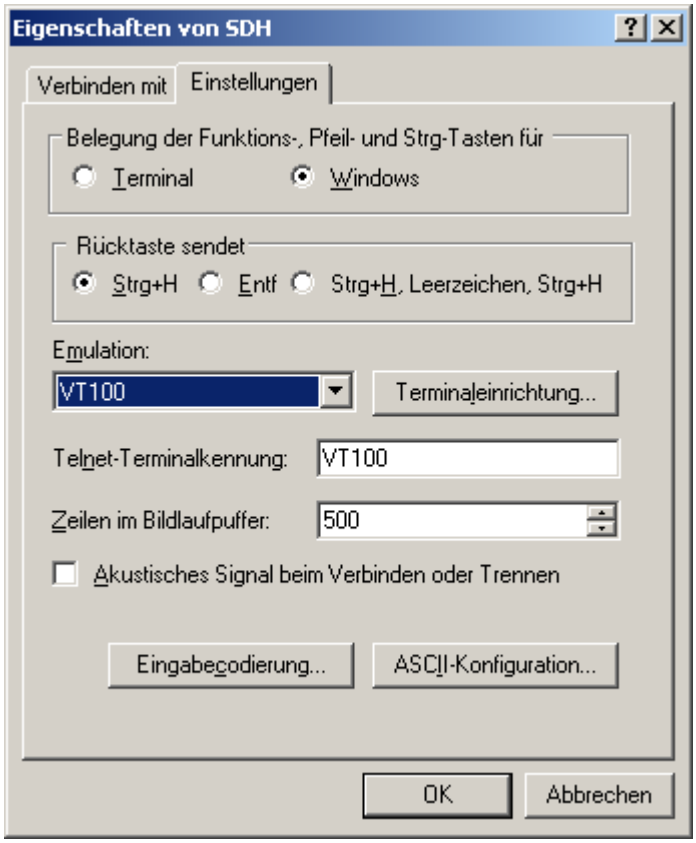

Figure 5: Further settings: Function, cursor and CTRL-keys for `Windows`, Terminal Emulation for `VT100`. After this is set up press `ASCII-Konfiguration...` before pressing OK.

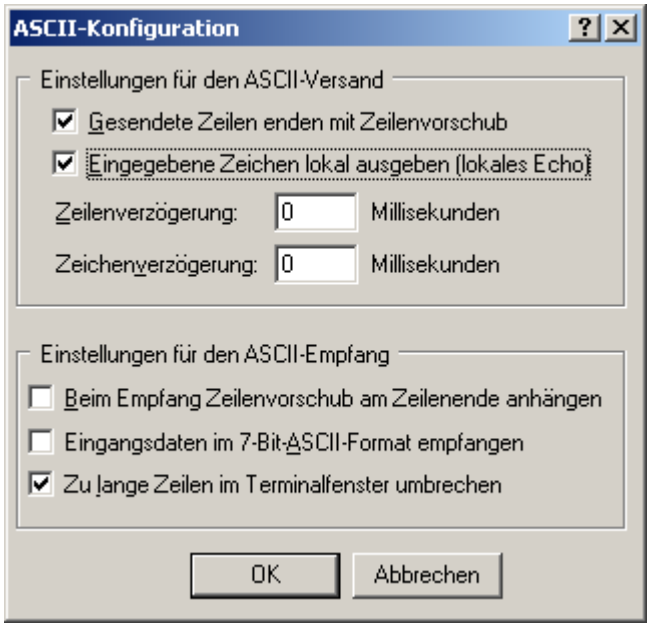

Figure 6: ASCII-configuration: Send CR/LF at line end and enable local echo. Then press OK to close this window, and OK again in the previous window.

Before continuing you should then save the settings with `File→Save as` for future re-use! The saved file will have a *.ht file extension and when double clicked in an explorer window it starts the HyperTerminal program with the just configured settings directly.

2.2. Step by step procedure

To start the actual calibration process we assume the following:

- The SDH is switched off
- The PC that is connected to the SDH is switched on
- The terminal program on the PC is running and is configured as described above in section 2.1
-

2.2.1. Step 1: Enter configuration mode

With the just mentioned prerequisites, you can now switch on the SDH. The SDH will detect that a terminal program is listening on its RS232 line and it will print a message and it will query whether to enter configuration mode (see Figure 7). This is indicated by a line like „`Press the <SPACE> bar to enter the configuration utility now... 3`“ in the terminal program. You have 3 seconds to press the space key. If you miss the 3 seconds time-out, then the SDH will start up normally and will not enter configuration mode. In that case simply switch off the SDH, wait for 5 seconds and start over with step1.

```
**********************************************************************
Project name:     SDH2-HandControl
Program name:     SDH2 Low Level Control (LLC)
SoC ID:           0x7C3988DE, built on 2008-05-09 15:58 GMT
Firmware release: 0.0.1.8, built on 2008-05-21
CPU-Frequency:    75000000 Hz (75 MHz)
CPU-Name:         ll_cpu
**********************************************************************
Press the <SPACE> bar to enter the configuration utility now... 3
```

Figure 7: Start message of SDH. Press space within 3 seconds after power on to enter configuration mode

If you pressed the space key in time then the SDH successfully enters the configuration mode, and displays a message like that shown in Figure 8.

```
************************************************************
*                SDH CONTROLLER SETUP UTILITY              *
************************************************************
*                                                          *
* This configuration utility allows you to setup certain   *
* parameters of your controller. To display possible commands, *
* type 'help' to the command line.                         *
*                                                          *
* <c> 2006 IPR, University of Karlsruhe, all rights reserved   *
* <c> 2007 SCHUNK GmbH & Co. KG                            *
*                                                          *
************************************************************
```

Figure 8: Message from SDH that indicates that the configuration mode has been successfully entered

2.2.2. Step 2: Start calibration procedure

Now that the configuration mode is active you can enter commands via keyboard. To get a list of the available commands type `help` and press ENTER.

For the calibration of the absolute encoders you need only the commands explained in detail here. You can calibrate the proximal and distal joints of all fingers in one step and / or you can calibrate the root joint in another step.

Step 2a: Calibrating the proximal and distal joints of all fingers (joints 1-6)

To calibrate all the proximal and distal joints of all fingers type "`absenc measure finger`" and press ENTER. If you typed something wrong, then the SDH will reply with an error message or it will just ignore the command. In that case simply try again. In case of success a message according to Figure 9 is shown.

```
Please move finger joints 1-6 manually outwards into the mechanical stop
The measurement runs continuously, until you press <ENTER> to accept the
current value.
(Press <S> to set current configuration temporarily)
```

Figure 9: Message printed by SDH after the measurement of the absolute encoders for the proximal and distal joints of the fingers has been started.

As indicated you must now manually move all the proximal and distal joints outwards into the mechanical stop, as shown in Figure 10.

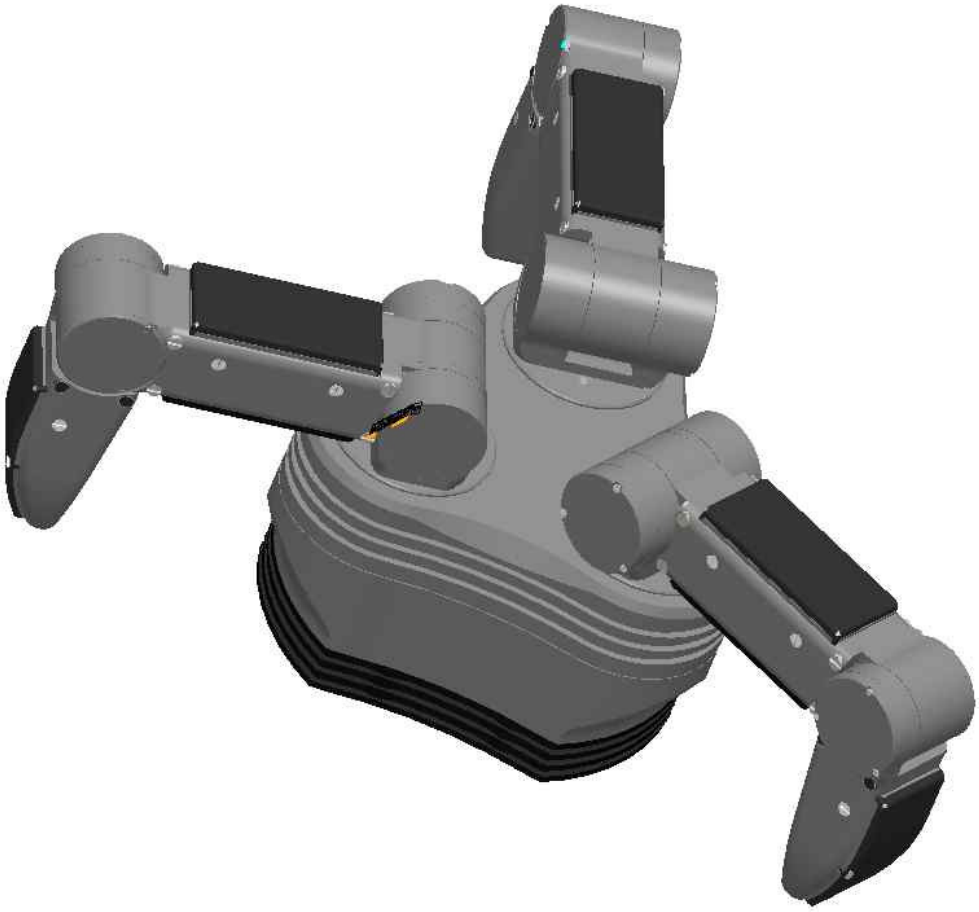

Figure 10: The proximal and distal joints of the SDH must be moved manually to the indicated positions while performing the `absenc measure finger` command. The position of joint 0 does not matter here and could be anywhere (here joint 0 is at 45°).

After the indicated position is reached press “S” then ENTER. The SDH then asks `Save the entered configuration data to the EEPROM(Y/N)`. To save the new calibration persistently please press „Y“ and ENTER. This will store the needed angle offset values to translate from the raw absolute encoder values to the calibrated absolute joint positions.

Step 2b: Calibrating the root joint (joint 0)

Calibrating the root joint 0 is a little bit more complicated, since it cannot be moved manually. (The gear box of joint 0 is not back driveable.) Therefore you must move the joint 0 to a well defined position by repeatedly pressing buttons in the terminal program on the PC. To start the calibration of the root joint type `absenc measure root` and press ENTER. The SDH then prints a message like that shown in Figure 11.

```
Please bring axis 0 to position 0 deg, i.e. the proximal joints of finger 0
and finger 2 are in coaxial position.
- To decrement the axis 0 angle press <-> (Minus) first
  then press <RETURN> repeatedly to decrement the angle step by step
- To increment the axis 0 angle press <+> (Plus) first
  then press <RETURN> repeatedly to decrement the angle step by step
- After the 0 position is reached press <S> and <RETURN> to save the data
- You must confirm the saving by pressing <Y> and <RETURN> again,
  or press <N> to not store the current position as 0.
```

Figure 11: Message printed by SDH after the measurement of the absolute encoders for the root joint has been started.

As indicated you must now bring the joint 0 to its zero position. To decrement the position press “-“ (minus) once first, then press ENTER or RETURN repeatedly. Each press will decrement the angle one step. To increment the position press “+” (plus) once first, then press ENTER or RETURN repeatedly. Each press will increment the angle one step. You can switch directions (+/-) any time. You are finished when the proximal and distal limbs of the fingers 0 and 2 are parallel, as shown in Figure 12. After the indicated position is reached press “S” then ENTER. The SDH then asks `Save the entered configuration data to the EEPROM(Y/N)`. To save the new calibration persistently please press „Y“ and ENTER. This will store the needed angle offset value to translate from the raw absolute encoder value to the calibrated absolute joint position.

Figure 12: The root joint 0 of the SDH must be moved to the indicated position by key presses while performing the `absenc measure root` command. The positions of the other joints 1-6 do not matter here and could be anywhere, but the positions shown in the figure make the estimation of the correct position of joint 0 more easy.

2.2.3. Step 3: Exiting configuration mode

To finish the calibration procedure you must leave the configuration mode. This can be done by simply restarting the SDH, i.e. switch off the power, wait for 5 seconds, then switch on power again. If the terminal program is still connected it will display the start message and the query again. You should now not press the space key and let the SDH start normally.
After the SDH has started normally it displays the current absolute positions of all joints according to the stored calibration offsets, see Figure 13 for an example.

```
After homing and position offset corrected
axis[0]= 0.0 deg
axis[1]=-90.11 deg
axis[2]=-88.64 deg
axis[3]=-90.02 deg
axis[4]=-90.00 deg
axis[5]=-90.53 deg
axis[6]=-90.31 deg
```

Figure 13: After normal start the SDH displays the current absolute axis positions according to the previously stored calibration offsets.