HDAQ2USB User Guide Version 1.3
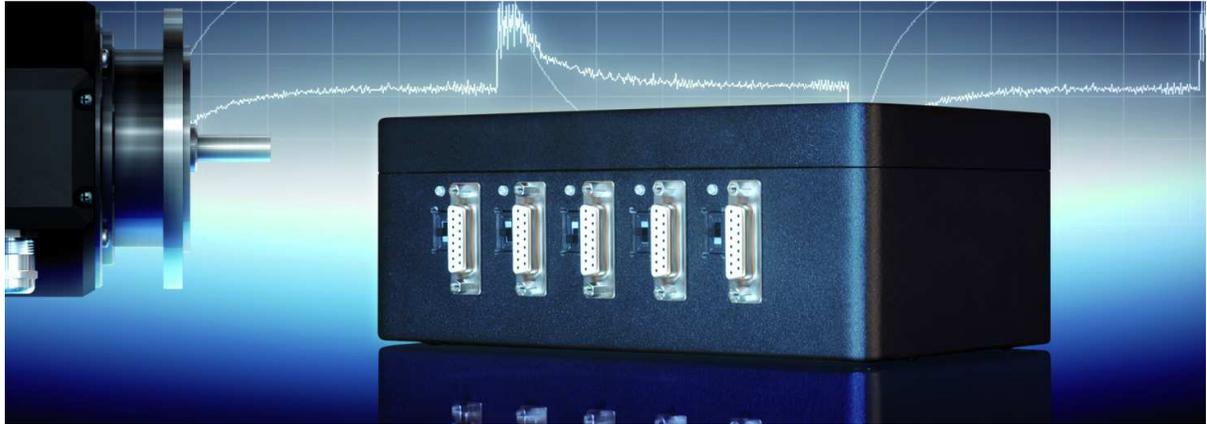
Table of Contents

1 Introduction

What is the purpose of the HDAQ2USB?
What kinds of problems can be solved with it?
What capabilities does it have?
What are the prerequisites for using it?

The HDAQ2USB is a measurement and analysis device for industrial rotary encoders. It has a USB 2.0 PC interface and can capture analog sine/cosine, square-wave and SSI encoder signals. It features integrated digital signal processing hardware to calculate the encoder's position and velocity information. The data is displayed on the PC with a program that supports both 32 and 64-bit platforms. It can also be used to save the data, and analyze it in the frequency domain.

2 System Requirements

A PC with following requirements is needed:

- Microsoft Windows XP or Windows 7
- USB 2.0 interface
- Minimum 512 MB of RAM (1GB recommended)
- Minimum 100 MB of free hard disk space

3 Hardware

The HDAQ2USB is an FPGA based measuring system, operating with an internal clock frequency of 64 MHz. There are 5 physical inputs, which have the following numbering order from left to right:

Input **4**:	Input **5**:	Input **1**:	Input **2**:	Input **3**:
HTL/TTL	HTL/TTL	Sine/Cosine & SSI	Sine/Cosine	Sine/Cosine

N.B. Input 1 can be used to connect to either a sine/cosine or an SSI encoder

Figure 1: a) Encoder inputs   b) USB interface and power supply

For each sine/cosine input, the analog A and B signals are sampled using separate 12-bit Analog-to-Digital converters (ADCs) that are triggered using the same sample clock. This allows the signals to be sampled at exactly the same time. The sample rate for input 1 is 20 MSPS (million samples per second). The sample rate for the input 2 and 3 is 1 MSPS. Inputs 4 and 5 are evaluated by an RS422 receiver with a 10ns switching time.

3.1   Encoder Inputs

The input parameters for each of the inputs are as follows:

Input 4:
- Square-wave input (TTL/HTL, A+, A-, B+, B-, R+, R-)
- Maximum input frequency: 500 kHz
- Output supply voltage: 5 V or V_B
- Connection: D SUB 15

Input 5:
- Square-wave input (TTL/HTL, A+, A-, B+, B-, R+, R-)
- Maximum input frequency: 500 kHz
- Output supply voltage: 5 V or V_B
- Connection: D SUB 15

Input 1:
- Sine/cosine input (1 V_{SS}, A+, A-, B+, B-, R+, R-)
- Maximum input frequency: 500 kHz
- SSI interface
- Output supply voltage: 5 V or V_B
- Connection: D SUB 15

Input 2:
- Sine/cosine input (1 V_{SS}, A+, A-, B+, B-, R+, R-)
- Maximum input frequency: 200 kHz
- Output supply voltage: 5 V or V_B
- Connection: D SUB 15

Input 3:
- Sine/cosine input (1 V_{SS}, A+, A-, B+, B-, R+, R-)
- Maximum input frequency: 200 kHz
- Output supply voltage: 5 V or V_B
- Connection: D SUB 15

!   Attention: HTL encoders must only be connected to inputs 4 and 5. Inputs 1, 2 and 3 will be damaged if HTL signals are connected.   !

3.2 Terminating Resistors

The sine/cosine and square-wave inputs are not terminated by default. In the case that an encoder is connected directly to the HDAQ2USB as shown in Figure 2 a), a terminating resistor adapter is needed as shown in Figure 3. Measuring an un-terminated encoder will not damage the hardware, but can cause some signal distortion. If the HDAQ2USB is used to observe encoder signals, e.g. between an encoder and drive inverter, no terminating resistor should be required as one should already be present in the circuit, as shown in Figure 2 b).
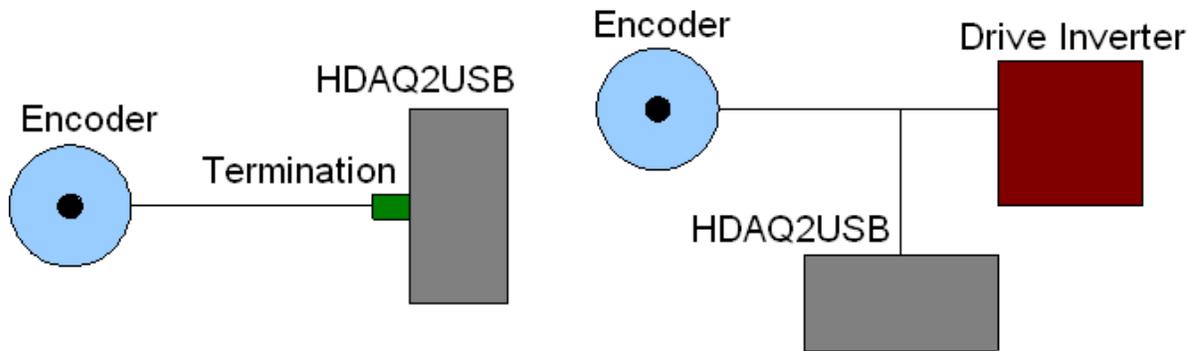

Figure 2: a) Encoder connected directly to HDAQ2USB   b) HDAQ2USB observing encoder signals

Figure 3: Terminating resistor adapter

3.3 Power Supply

The HDAQ2USB requires a supply voltage in the range of 10 - 30 V, hereon named V_B. The unloaded current consumption at 12 V is typically 150 mA. The HDAQ2USB provides an output supply voltage to each encoder connection. Each output supply voltage is switchable between 5 V, V_B and open circuit (no output voltage). An LED above the switch next to the input indicates the provided voltage level.

Switch position	LED Color	Output Supply Voltage to Encoder
Up	Green	5 V
Center	Off	Open Circuit (No supply voltage)
Down	Orange	V_B (10 – 30 V)

! Attention: An output supply voltage above the specified rating can damage the encoder! !

3.4 Pin Assignment

Sin/Cos, HTL/TTL and SSI Inputs:

D-SUB 15 Pin   Assignment
1   A+
2   A-
3   B+
4   B-
5   R+
6   R-
7   CLK+   (SSI, only at input 1)
8   CLK-   (SSI, only at input 1)
9   DAT+   (SSI, only at input 1)
10   DAT-   (SSI, only at input 1)
11, 12   Output Supply Voltage: 5 V / - / V_B
13, 14   0 V
15   Shield

Power Supply:

M8 Pin   Assignment
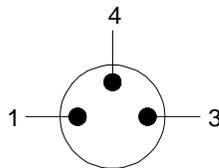1 V_B (10 – 30 V)
3   0 V
4   Shield

Figure 4: Power supply mating connector - Phoenix Contact SACC-M8FS-3CON-M-SW

4 Signal Processing

4.1 Sine-wave Inputs

In order to calculate the position and velocity of a sine/cosine encoder, the A and B signals are firstly normalized using offset and amplitude correction. Then the position is calculated using the arctangent method, and the resulting signals for position and velocity are then smoothed using an adjustable low-pass digital filter. The raw A and B signals can also be measured directly through an adjustable low-pass digital filter. Therefore other analog signal sources such acceleration sensors can also be evaluated.

4.2 Square-wave Inputs

The position information for square-wave signals is derived using a 'four edge evaluation' method at a cycle rate of 64 MHz. The velocity evaluation is performed with a gate time of 1 ms by means of a combined edge count and cycle duration method. Glitches with duration less than 1.5 µs (frequencies above 650 kHz) are ignored. The position and velocity signals are then smoothed using an adjustable low-pass digital filter.

4.3 Digital Filtering

Each digitized sine/cosine A and B signal, and each calculated position and velocity signal for sine/cosine and square-wave encoders is passed through a configurable 64 value over-sampling low-pass digital filter before being transferred to the PC. The cut-off frequency for each filter can be set as one of the following values:

- 194 Hz
- 389 Hz
- 777 Hz
- 1,554 Hz
- 3,108 Hz
- 6,217 Hz
- 12,434 Hz
- 24,868 Hz

4.4 SSI Input

Input 1 also supports receiving SSI signal data. N.B. this is listed as input 6 in the PC software. The HDAQ2USB acts as an SSI master with configurable SSI clock frequency, cable length and the monoflop time used by the SSI slave. The interpretation of the received SSI data is configurable. Up to 8 different data values or 'Words' can be extracted from the received data and plotted separately. For each Word it is possible to configure the bit-length (1 – 32 bits), the type of data (position / velocity / raw) and whether the data is signed or unsigned, see 5.5.3.2.3. No oversampling is implemented for the SSI input. The input is triggered by the sample clock within the device. See Appendix B – SSI Data Block Configuration Examples.

5   PC Software

The HDAQ2USB PC software is used to configure the device and to display the captured data. Additionally it is possible to save measured data in order to load it later for further evaluation. The configuration of the hardware device and the graphical display can be saved to and loaded from a file, and the current configuration is automatically saved on exit and restored when the program is next run.

The user interface can be divided into three main areas as shown in Figure 5. Area '1' is the toolbar, area '2' is the control block, and area '3' contains the currently configured graphs.
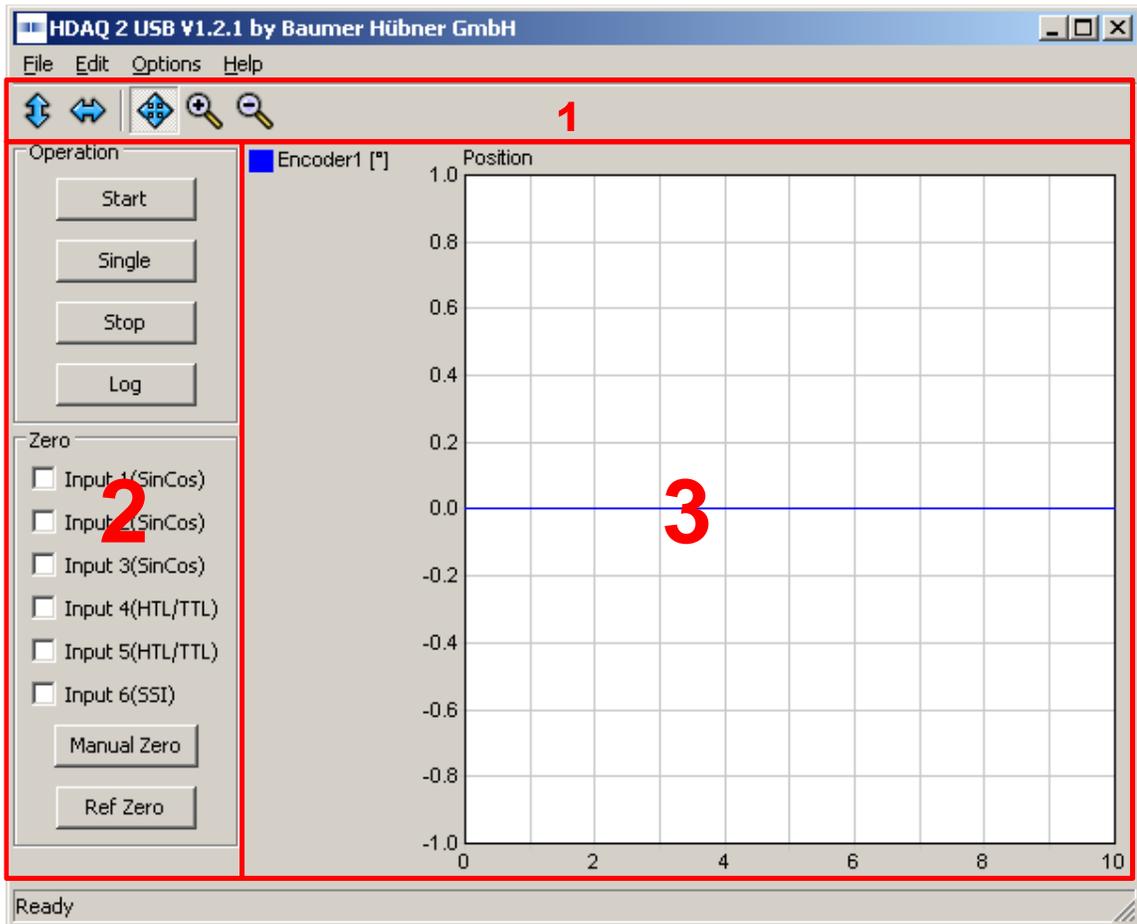

Figure 5: Main areas of the HDAQ2USB user interface.

Within each graph area there are several clickable zones that are highlighted with a black surrounding box when the mouse is moved over them. The clickable zones are:

- The title of the graph and the area below the channel names: Used to configure the graph settings, see 5.1.
- Each channel name: Used configure the channel settings, see 5.2.
- Within the grid of each graph: Used to for panning and zooming, see 5.3.
- The x and y-axis of each graph: Used for auto-scaling the axes according to the sampled data, see 5.3.

5.1   Graph Settings

Performing a left or right click on the graph title or below the channel names displays a context menu as shown in Figure 6. It contains the following items:

- *Add graph*: A new graph is added below the existing graphs.
- *Insert graph*: A new graph is added below the selected graph.
- *Edit graph*: The Graph Settings dialog is opened for the selected graph, see 5.1.1.
- *Remove graph*: The selected graph is deleted.
- *Add FFT graph*: A frequency domain view of the selected graph as added, see 5.4.

There is no in-built limit for the total number of graphs, or the total number of channels per graph.
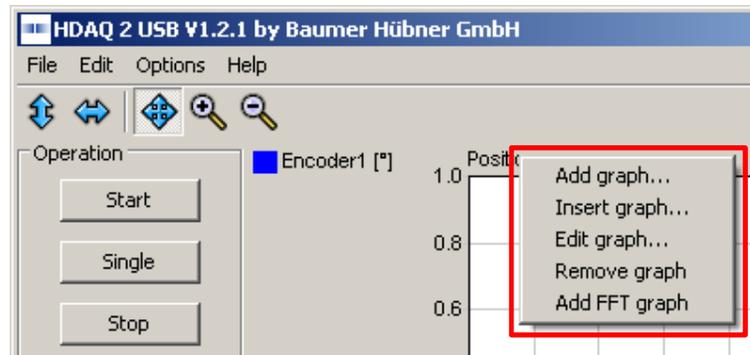

Figure 6: Context menu of a graph

5.1.1 Graph Settings Dialog

Opening the Graph Menu provides the following options:
- *Caption*: Sets the title of the graph
- *MaxValue*: Sets the maximum value for the 'stop on out of range' function
- *MinValue*: Sets the minimum value for the 'stop on out of range' function
- *Stop on out of range*: When enabled and the program is capturing data in continuous mode, the measurement will be stopped after the current measurement if any data lies outside the range defined by *MaxValue* and *MinValue*. The out-of range area is displayed on the graph as a dark grey background.
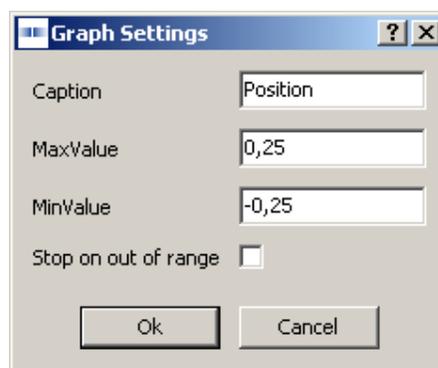

Figure 7: Graph Settings Dialog

5.2 Channel Settings

Each graph can have several channels. Clicking on the name of a channel opens a context menu with the following options:

- *Add channel*: Adds a channel to the graph.
- *Insert channel*: Adds a channel to the graph below the selected channel.

- *Edit channel*: Opens the channel setting dialog, see section 5.2.1.
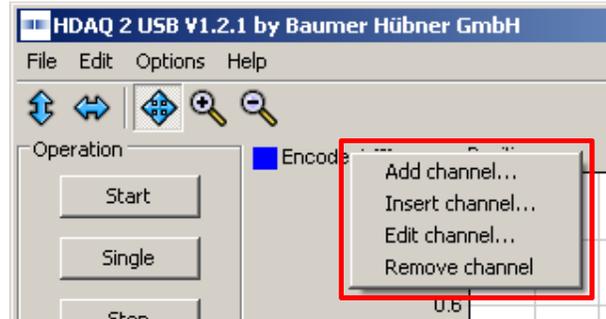- *Remove channel*: Deletes the selected channel.

Figure 8: Context menu of a channel

5.2.1   Channel Settings Dialog

The Channel Settings dialog provides the following options for the selected channel:

|	
Caption	Sets a name for channel
Input	Selects the hardware input 1 to 6 (input 6 being SSI)
Channel	Depending on the input type: • *Sine/cosine & HTL/TTL*: *position, velocity, A, B, R* (zero-pulse) • *SSI*: SSI Words, as configured in the SSI section of the Settings dialog, see 5.5.3.2.3.
Operation	*none, add, subtract* When add or subtract is selected the Input2 and Channel2 fields are enabled, allowing a second data source to be selected. The plotted data is the result of the mathematical operation between the two data sets.
Unit	Depending on the input channel, a list of suitable units is given. (The plotted data is scaled appropriately.)
Invert	Inverts the data
Offset	Applies a fixed offset to the data
Color	Sets the color used to plot the channel
Display Value	Displays a data value below the channel name showing the last value for the current measurement
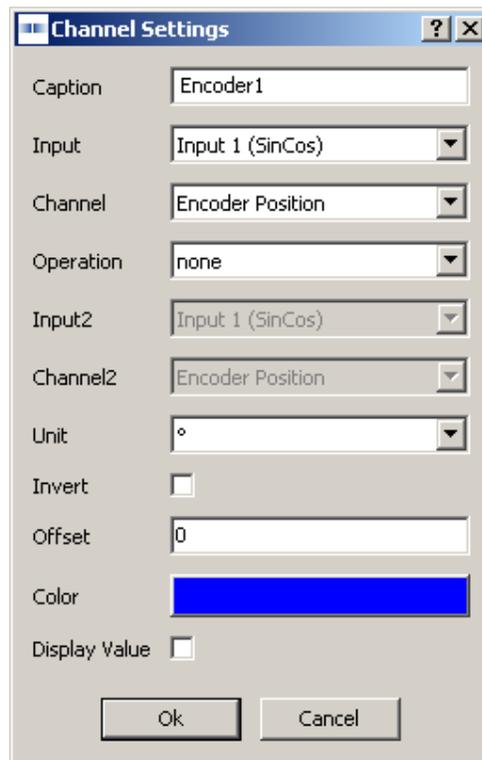
Figure 9: Channel Settings Dialog

5.3 Zooming, Panning and Auto-scale

5.3.1 Zooming

In order to zoom in or out within a graph, firstly click on the respective magnifying glass icon in the toolbar. Then click and drag within a graph area to select the desired viewable range. The zoom out function operates in an inverse manner – the smaller the selected range, the further the graph will zoom out.
The mouse wheel can also be used to zoom in and out.

5.3.2 Panning

Once a graph has been zoomed in, click on the crossed arrow icon in the toolbar to switch to panning mode. Click and drag within the graph to pan it in either direction.

5.3.3 Auto-scale

- Click on the x or y axis of a graph to auto-scale it according to the range of the data in that dimension.
- Click on the horizontal arrow icon in the toolbar to auto-scale the x-axis of all of the graphs.

- Click on the vertical arrow icon in the toolbar to toggle the periodic auto-scale function, which auto-scales the y-axis for all of the graphs every second.

5.4 Frequency Domain Analysis

It is possible to view captured data in the frequency domain. To do this, open the context menu for an existing graph by clicking on the title or below the channel names, and select 'Add FFT graph'. In continuous capture mode the FFT is continually updated. Data saved in a MATLAB file can also be loaded and analyzed in the frequency domain. The FFT graph is essentially another view of the same underlying data. Therefore the channels shown and their configuration are exactly the same as the time domain graph to which it belongs. Removing the time domain graph will also remove the FFT graph. The displayed frequency range is half of the global sampling frequency which is set in the Settings menu, as per the Nyquist Theory.

5.4.1 FFT Settings Dialog

Opening the graph context menu for an FFT graph and selecting Edit Graph, will open the FFT Settings dialog. The options are:

- *FFT dB Scale*: Uses a logarithmic decibel scale for the y-axis.
- *FFT Window*: Selects the windowing function used on the data before the FFT is performed.
- *FFT Number of Averages*: Enables the display averaging function which can be useful for smoothing out the spectral noise floor. It performs the required number of FFTs and averages the results. This is performed after converting to a logarithmic scale (when enabled). The total FFT range is the FFT Size multiplied by the Number of Averages. For example, when the FFT Size is 8,192 and the Number of Averages is 10, then the FFT range is 81,920 samples. A value of zero is the same as a value of one, i.e. no averaging is performed.
- *FFT Size*: Limits the number of samples used to perform the FFT. A value of zero performs the FFT on the entire data set.
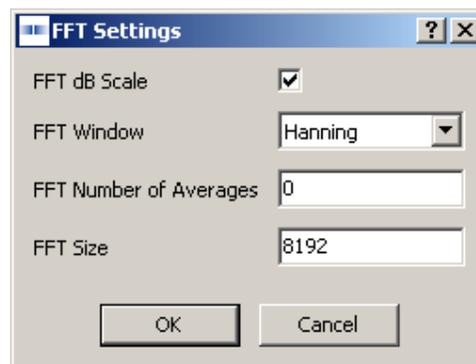

Figure 10: FFT Settings Dialog

5.4.2 Panning in the time domain

When the FFT range (FFT Size x Number of Averages) is smaller than the viewable data in the time domain, then the FFT is not performed on all of the viewable data. The FFT range is therefore highlighted in the time domain with a white background, and the rest of the data is highlighted with a grey background, see Figure 11. The FFT range always starts from the left hand side of the graph. Therefore panning the time domain will change the data shown within FFT range, and therefore the data on which the FFT is performed. The FFT graph is continually updated as the time domain graph is panned. N.B. if the FFT range is large, panning in the time domain will consume significant CPU time.
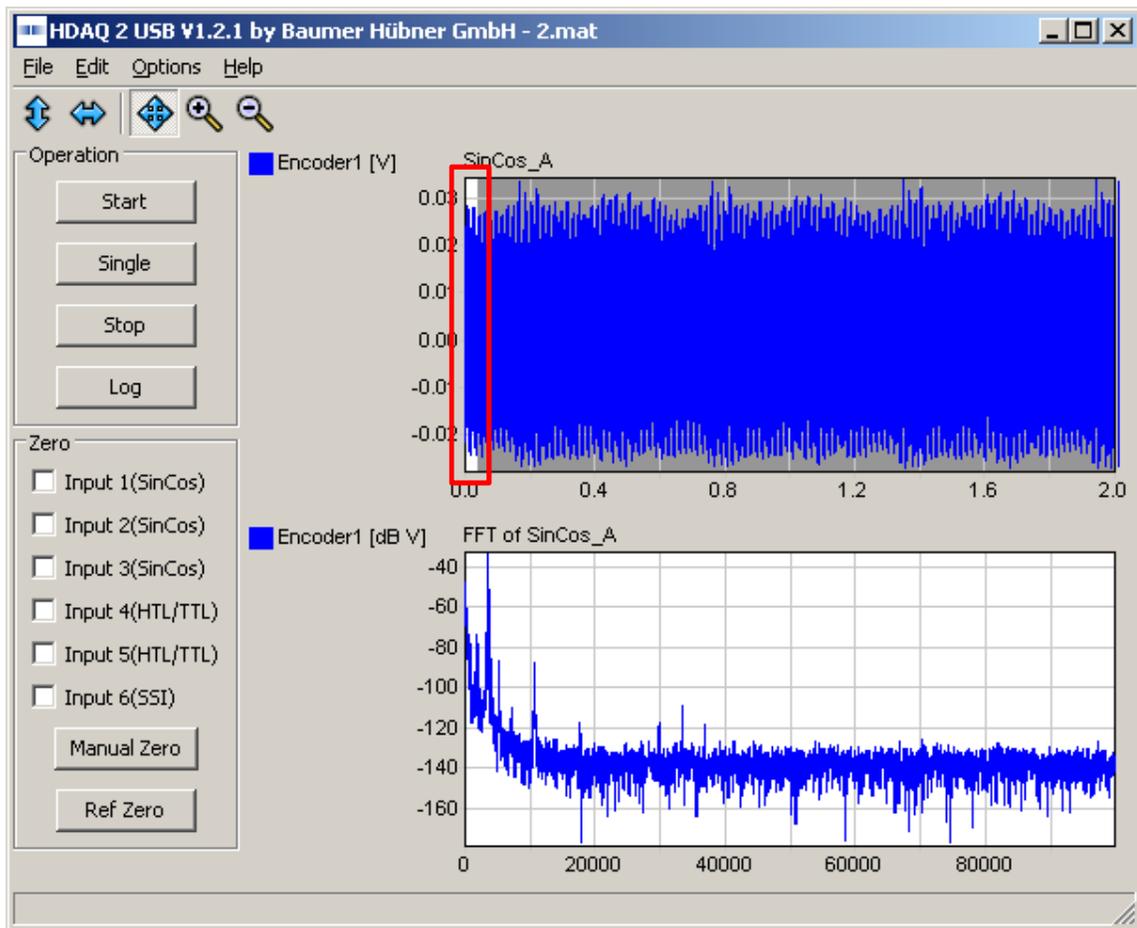
Figure 11: Example FFT graph showing the FFT range highlighted with a white background

5.4.3 Zooming in the time domain

If the time domain graph is zoomed in so that the viewable range is smaller than normal FFT range (FFT Size x Number of Averages), then the FFT Size is limited to the viewable range divided by the number of averages, so that the FFT range is always less-than-or-equal to the viewable range. In other words, zooming in to a small area of the time domain graph limits the FFT range to the visible data. This can be useful for analyzing dynamic data with fundamental frequencies that change considerably w.r.t. the total measurement time, but have localized periods of consistency that can be easily be identified and selected for frequency analysis.

5.5 Main Menu

5.5.1 File Menu

- *Load Configuration*: Load an existing configuration file. All current settings will be replaced with those loaded.
- *Save Configuration*: All current settings, including the HDAQ2USB device settings, are stored to a file.
- *Load Data*: Data is loaded from MATLAB (.mat).
- *Save Data*: The currently sampled data is stored to a MATLAB (.mat) or CSV file.

5.5.2 Edit Menu

- *Add Graph*: An additional graph is added below the last graph.

5.5.3 Options Menu

Settings regarding the HDAQ2USB and the PC program can be found here.

5.5.3.1 Connect

All of the PC's USB connections are analyzed in order to establish whether a HDAQ2USB device is connected. If only one device is connected, the program connects automatically to it. Otherwise a dialog is shown to select the device with which the program should connect.

5.5.3.2 Settings Dialog

The Settings dialog box (see Figure 12) is used to change the general program settings and the configuration for each encoder input.

The general program settings are:

- *Sample Rate*: Number of data samples per second
- *Display Time*: Time period of the data displayed for each graph
- *Log Time*: Time period of the sampled data when the Log function is used.
- *Graph Line Width*: Sets the width of the line displayed in the graphs.
- *Value on package loss*: When data loss during measurement occurs, this value is plotted instead of the measured data.

The lower part of the dialog consists of 6 tabs to configure the settings for each input of the HDAQ2USB. Note that the sixth channel (SSI) is physically connected at input 1. All specific settings of an encoder must be set here to ensure proper operation and signal evaluation.
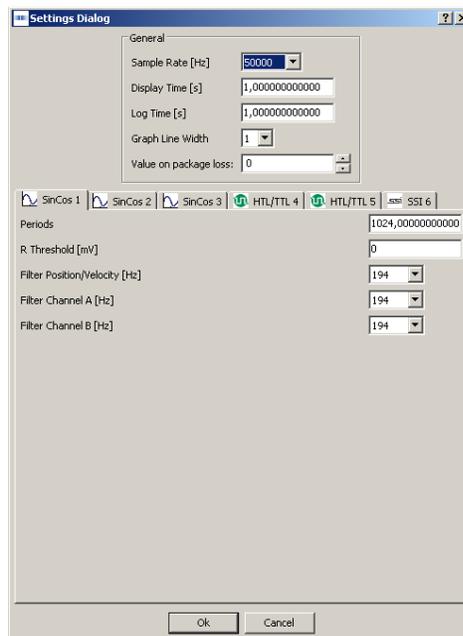

Figure 12: General settings and input configuration settings

5.5.3.2.1 SinCos 1, SinCos 2, SinCos 3

Inputs 1 to 3 are intended for use with sine-wave encoders - see Figure 12 for the available settings. The 'Periods' option configures the number of sine-wave cycles per turn or per meter. The 'R Threshold' option determines the switching point of the zero-pulse. The 'Filter Position/Velocity' option selects a low-pass filter with which the signals are filtered. Channels A and B also have configurable low-pass filters.

5.5.3.2.2 HTL/TTL 4, HTL/TTL 5

The inputs 4 and 5 are designed to capture TTL and HTL signals. The 'Periods' option sets the number of square-wave cycles per turn or per meter. The 'Filter Position/Velocity' option selects a low-pass filter with which the signals are filtered.
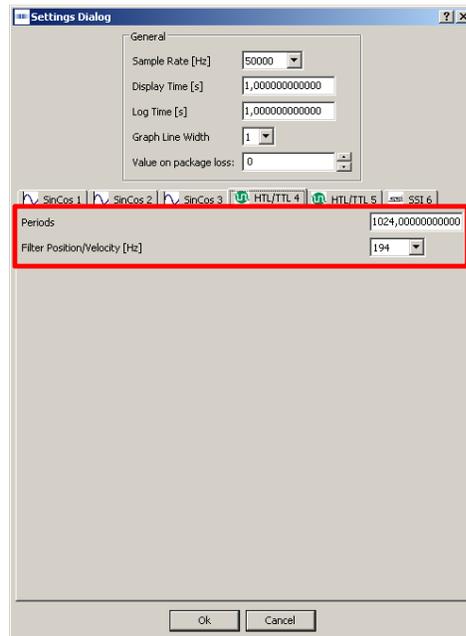

Figure 13: Square-wave signal settings

5.5.3.2.3 SSI 6

The SSI 6 input is physically identical to input 1. The clock frequency and the monoflop time must be specified for the SSI master (HDAQ2USB). To compensate for the propagation delay present in long cables, the cable length in meters can be adjusted. For sources using gray coding the checkbox can be enabled. Only Gray code decoding of the whole SSI data block is supported.

The SSI data block can be interpreted as up to 8 separate data 'Words'. Each Word can be up to 32 bits long and can contain position, velocity or any other kind of (raw) data. The configuration for each Word is set in the 'Data Block Composition' area. The 'Number of Words' specifies the number of enabled Words. A maximum of 8 times 32 bits of data, or 256 bits, can be evaluated. The following settings for each Word (see Figure 14) are available:

- *bits total*: Number of bits for this data field including an optional sign bit
- *sign*: Indicates that the data has a sign bit (MSB of the data field)
- *type*: Type of data for this data field, either:
    - *position*: comprising of a single-turn, or combined single-turn and multi-turn value
    - *velocity*
    - *raw*: unit-less data
- *bits single*: Number of bits for a single-turn or position value
- *bits multi*: Number of bits for a multi-turn or position value
- *scale*: Data scaling factor (1.00 by default)
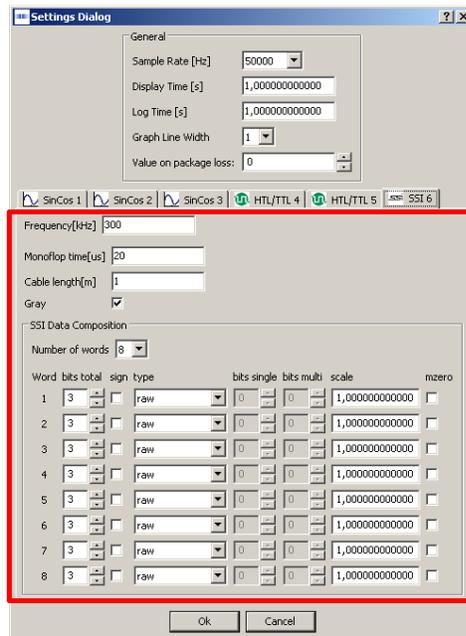- *mzero*: Enables the manual zero function, see 5.6.1.

Figure 14: General and data block SSI settings

Examples on how to configure the SSI data block can be found in Appendix B – SSI Data Block Configuration Examples.

5.5.3.3 Synchronize X Axis

It is possible to synchronize the x-axes of all of the graphs, meaning that panning or zooming within one graph automatically adjusts the x-axis of all of the other graphs accordingly. Note that this feature operates independently in the time and frequency domains. To activate this feature, enable the Sync X Axis option in the Options menu.

Figure 15: Sync X Axis

5.6   Control Block

The control block (see area 2 in Figure 5 on the left side of the window) is used to start repetitive measurement, perform a single measurement, stop the current measurement or perform a logging measurement. A logging measurement captures data for the time specified in the global settings and then saves the data to a file.

5.6.1   Zeroing

Whilst measurement is in progress, it is possible to adjust the vertical offset of the plotted data using the zeroing functions. Zeroing can be useful for comparing two or more signals against each other.

- *Manual Zero*: The selected inputs are each offset by the signal value received at the time the button is clicked.

- *Ref Zero*: The selected inputs are each offset by the signal value received when the next zero-pulse is received. N.B. this does not apply to the SSI input.

Checkboxes for enabling the zero function for each input are found in the Control Block. In order to use the manual zero function for SSI Words, the 'Input 6(SSI)' checkbox must checked as well as the respective Words in the SSI section of the Settings dialog, see 5.5.3.2.3.

5.7   Example Configuration

Figure 16 shows an example configuration with five signals in four graphs.

Figure 16: Example data captured from a sine/cosine encoder and a Ferraris sensor

Appendix A – Version History

Version v1.2.1 (11/2013)
- Supported SSI Words increased from 4 to 8
- FFT function added
- Hardware version 2 (unchanged)
- Firmware updated for 8 SSI Words

Version v1.2.0 (11/2010)
- SSI data can handle up to 4 configurable SSI Words. Each Word can be signed or unsigned and displayed as position, velocity or as raw data, whereby the position value can be divided into single, multi and single + multi turn value.
- Hardware is unchanged
- Firmware updated (Version 2.0)
- PC-Software v1.2.0 works starting from Firmware Version 2.0 (check at start of software)

Version v1.1.5
- A display of current values is added. Last display can be activated in the channel settings by activating the checkbox Current Value.
- The auto-scale function is revised. In active mode each second the graphs will be scaled to the data maximum.
- The Version of the PC-Software is shown in the title of the main window.
- Hardware is unchanged
- Firmware is unchanged (Version 1.0)

Version v1.1.4
- Aliasing in signal representation removed.
- Display-Settings are stored at normal program termination.
- Hardware is unchanged
- Firmware is unchanged (Version 1.0)

Version v1.1.3
- Overflow-Error for Math-Operation channel removed
- Hardware is unchanged
- Firmware is unchanged

Appendix B – SSI Data Block Configuration Examples

Example 1:

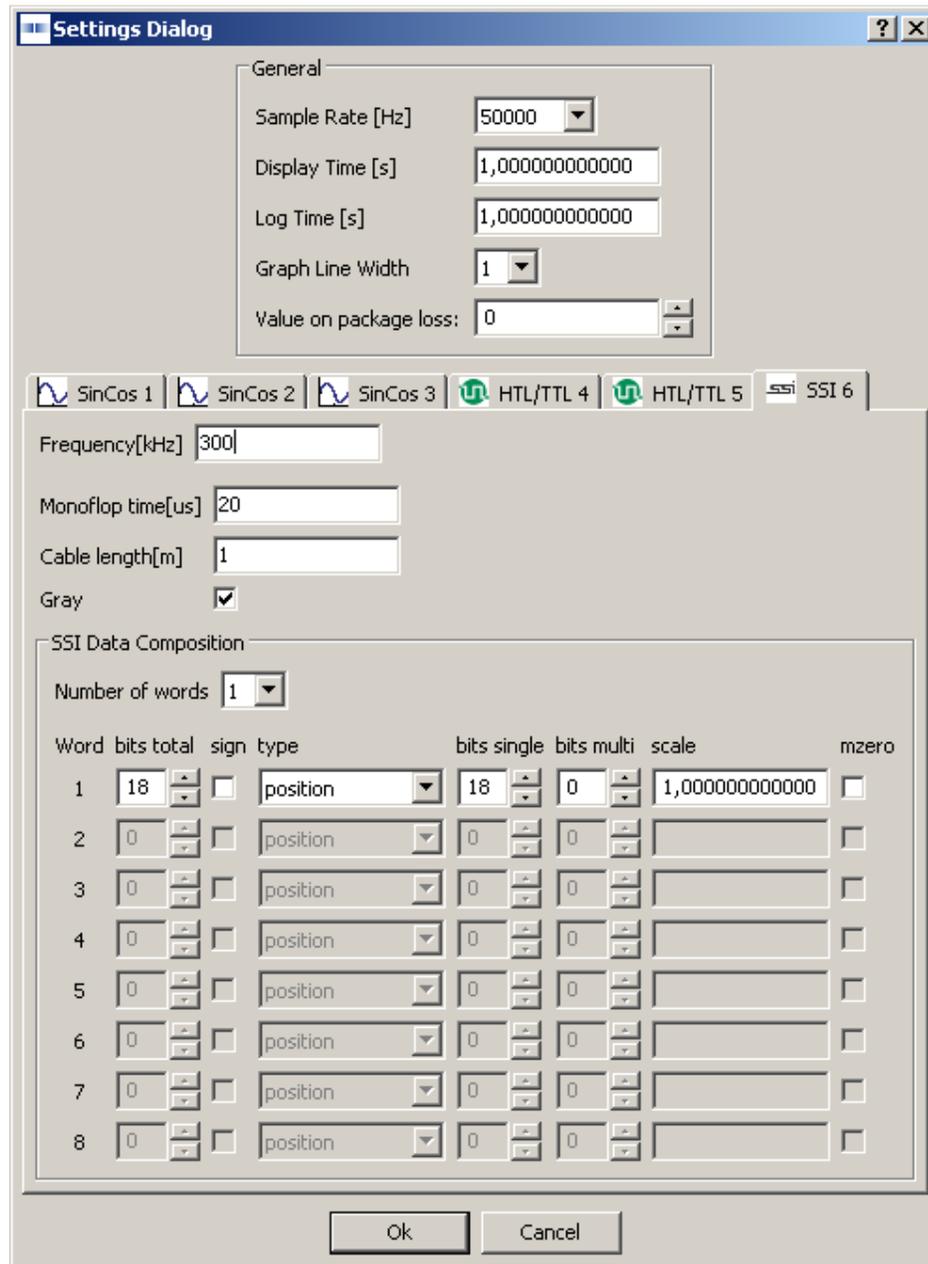18-bit single-turn Gray coded position

Figure 17: Example SSI configuration: 18-bit single-turn Gray coded position

Example 2:

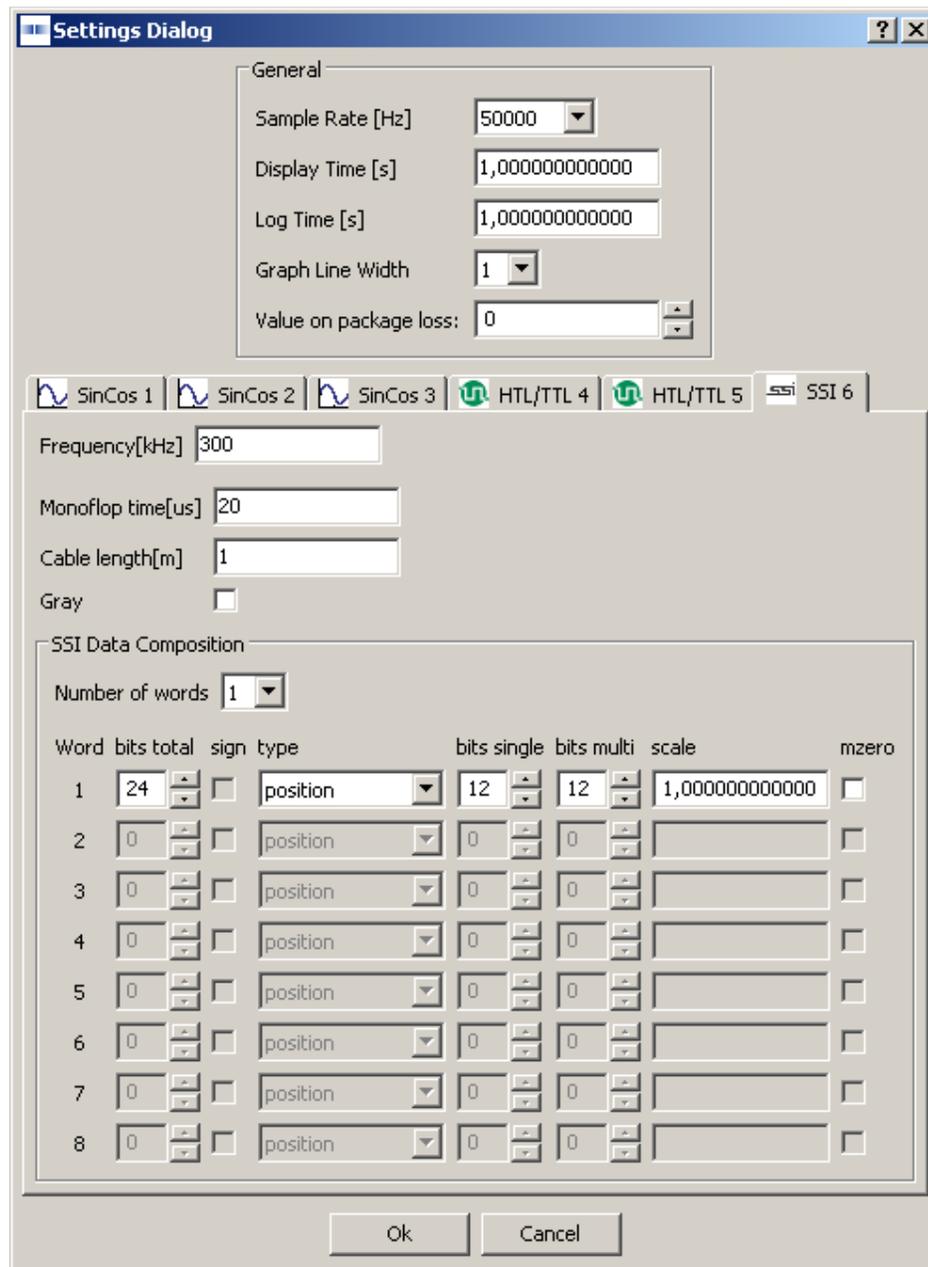24-bit (12-bit single-turn + 12-bit multi-turn) position

Figure 18: Example SSI configuration: 24-bit (12-bit single-turn + 12-bit multi-turn) position

Example 3:
12-bit multi-turn position
12-bit single-turn position

When the single and multi-turn positions need to be viewed as two different Words, this can be achieved using the raw data type for the multi-turn position. Since two Words are used, the order of data transmission must be taken into account (SSI sends MSB first). The multi-turn value is transmitted first, and therefore assigned to Word 1. This Word must be displayed as raw unsigned data value. Subsequently the single-turn Word is assigned as Word 2, thereby this Word is handled as ordinary position without a multi-turn component.
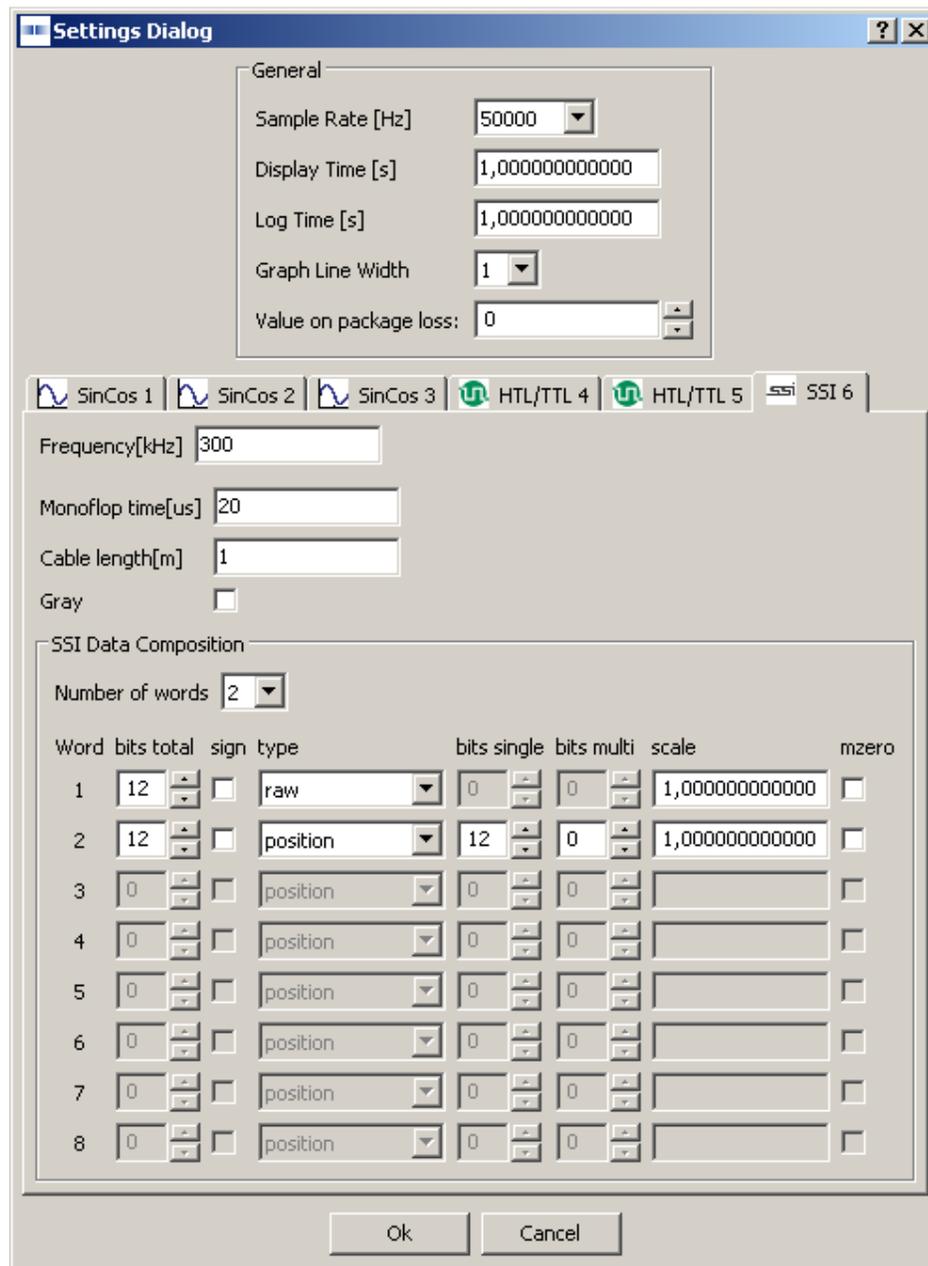

Figure 19: Example SSI configuration: 12-bit multi-turn position, 12-bit single-turn position

Example 4:

12-bit single-turn position
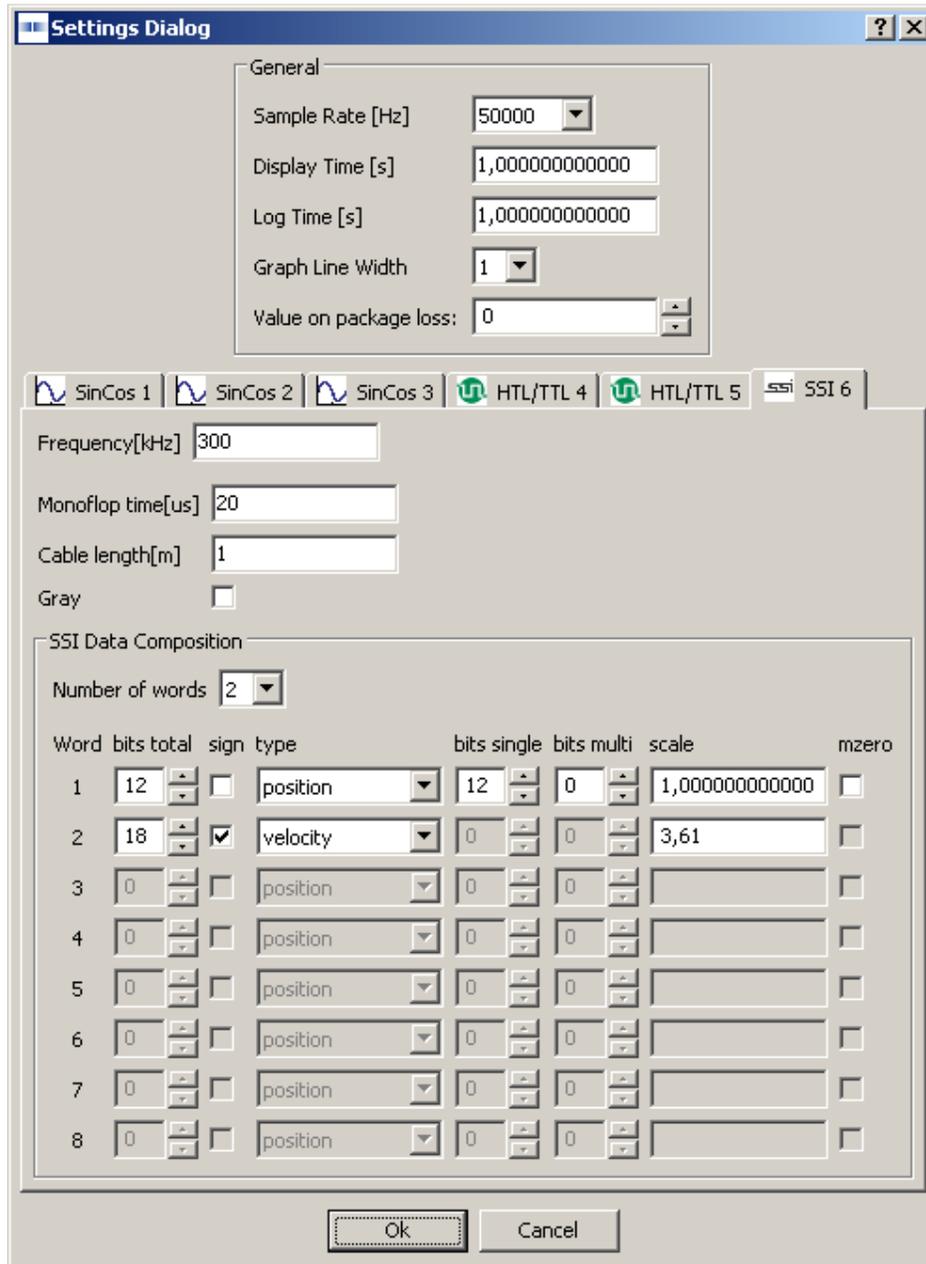18-bit signed velocity with 3.61 scaling factor

Figure 20: Example SSI configuration: 12-bit single-turn position, 18-bit signed velocity with scaling