Coil System CS681

Eight channel search coil system with
real time digital signal processing

User Manual

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1.0 Important Safety Instructions

Carefully read this chapter and follow the instructions before using the CS681.

- The CS681 is intended for research use only and has not been reviewed, certified, or approved for clinical purposes.
- All use of the CS681 must be in compliance with appropriate procedures.
- The CS681 has no approval / certification for applications on the human being and may never be used for such applications.
- Consider the possible risks for injuries to health before using the CS681.
- Only qualified personnel may operate the CS681, and only after becoming familiar with the concerning standards, regulations and possible risks.
- The signals applied to the coil frame may have hazardous voltage levels. An inappropriate application (touching the conductors or the coil frame, capacitive and / or inductive couplings etc.) can come for injuries to health. Do not touch any exposed parts when power is applied.
- The coil frame of the CS681 generates an AC magnetic field which can lead to injury to health. Inductive or capacitive coupling onto organisms and devices sensitive in this regard must be considered.
- Refer to the instructions within this manual for details on setting the correct line voltage. Check the correct setting of the line voltage selector before connecting the power cord.
- Use only the power cord certified for the country of use. The CS681 is grounded through the grounding conductor of the power cord. To avoid electric shock, the grounding conductor must be connected to earth ground. Before making any connections to the input or output terminals of the CS681, ensure that the CS681 is properly grounded.
- Use only the fuse type and rating specified for the CS681.
- Refer to the instructions within this manual for details on installing the CS681 so it has proper ventilation.
- Do not expose the CS681 to rain or moisture. Do not operate in wet or damp conditions. Do not operate in an explosive atmosphere.
- Unplug the power cord before cleaning the CS681. Use a damp, soft and lint-free cloth for cleaning. Do not use any cleansing agents or solvents.
- If you suspect there is damage to the CS681, have it inspected by qualified service personnel. Do not open the cabinet, dangerous high voltages are present inside the unit. No operator serviceable parts are present inside the unit. Refer servicing to qualified personnel only.
- In no event shall Primelec, its employees or its suppliers be liable for any injury, loss, claim or consequential damages of any kind.

2.0 Getting Started

The coil system CS681 is an eight channel search coil system for the linear detection of 3D eye and head movements. The system's ultra high accuracy and band-width guarantees effortless recording of not only saccades, vergence, smooth pursuit, vestibular and optokinetic eye movements but also of miniature eye movements: drift, tremor and microsaccades. Applications of the CS681 include neuro-physiological, ophthalmological, psychological, psychiatric, reading and visual studies.

The CS681 provides 8 recording channels for the simultaneous processing of up to 8 search coils. The processing is based on Primelec's enhanced amplitude detection (FFT). A high performance digital signal processor and a high speed field programmable gate array are used to detect the angular orientations of the search coils in real-time and to control the system.

The handling of the CS681 is straightforward and very user friendly thanks to the automatic tuning of the gain- and offset settings. All settings may also be controlled manually over the touch screen or over the USB interface with the included application software.

2.1 General Features

- User friendly menu controlled operation (LCD with touch screen)
- Easy to use, straightforward system configuration
- Nonvolatile memory for 10 user specific system configurations
- Automatic tuning of gain- and offset settings
- 8 recording channels, digital processing of up to 8 search coils in real-time
- Firmware upgradeable on location
- Ultra low-noise preamplifier
- Digital synthesized field signals
- USB 1.1 / 2.0 interface
- ActiveX control and application software included (Windows 2000 / XP)
- Digital and analog output data (USB interface and 24 analog outputs)
- Linear angular output data (horizontal and vertical) and raw output data
- Various coil frames applicable
- Various search coils applicable
- User selectable gain correction for the X-, Y- and Z-vectors per channel
- User selectable offset correction for the X-, Y- and Z-vectors per channel
- User selectable phase correction for the X-, Y- and Z-vectors per channel
- User selectable low-pass filtering per channel
- User selectable search coil polarity reversing per channel
- User selectable format of the analog outputs
- User selectable voltage swing of the analog outputs
- User selectable magnetic field attenuation
- User selectable magnetic field polarity reversing per axis
- Output data rate up to 8000 readings per second
- Recording range 360° in the horizontal plane, ± 80° in the vertical plane
- Warm Up Drift < 0.1° within 30 minutes, negligible after warm-up
- Resolution < 0.0002°
- Noise < 0.0028° RMS

2.2 Scope of Delivery

The scope of delivery depends on the solution you choosed. Please refer to Primelec's order confirmation for further details regarding the scope of delivery of the products ordered by you.

The scope of delivery of the coil system CS681 for a standard solution includes the following:

1 Main Unit

1 Coil Frame with Matching-Box

1 Preamplifier

1 User Manual

1 CD ROM with software and documentation

1 Cable 3 m (power cord)

1 Cable 5 m (field signals)
25 contacts pin connector D-SUB / 15 contacts socket connector D-SUB

1 Cable 5 m (preamplifier)
15 contacts pin connector D-SUB / 15 contacts pin connector D-SUB

1 Cable 3 m (USB)
USB Type A connector / USB Type B connector

1 Connector (analog outputs)
25 contacts socket connector D-SUB

2 Connectors (search coils)
9 contacts pin connector MICRO-T

2.3 System Installation

The system installation is described in chapter “3.0 System wiring“.

Caution:

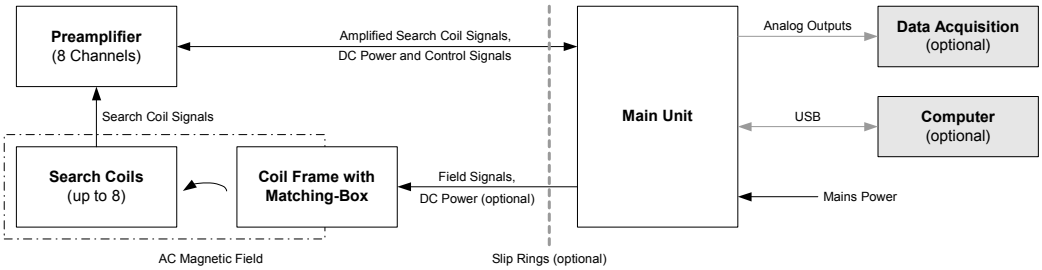
Read chapter “1.0 Important Safety Instructions“ before wiring and using the system!

3.0 System wiring

This section describes the system wiring. Please read chapter “4.0 System Description“ for a detailed description of the system.

3.1 Overview

The coil system CS681 basically consists of the following components:



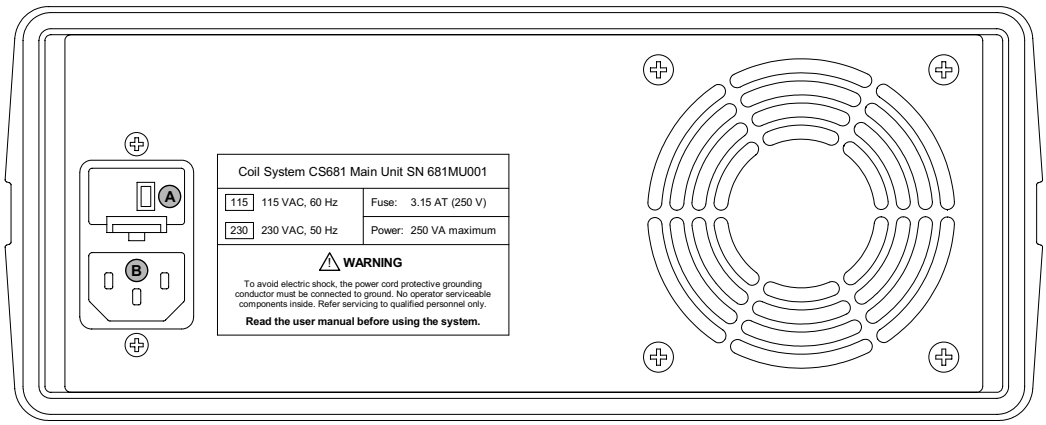
Notes:

- An external data acquisition system (not part of the delivery) may be used to capture the analog output signals from the system.
- An external computer (not part of the delivery) may be connected to the system’s USB interface.
- DC power for the matching-box is only required in conjunction with the optional version “Coil Frame with Removable Bars”. Use the appropriate cable to connect the matching-box to the main unit (3 x 2 twisted pairs for the standard coil frame, 4 x 2 twisted pairs for the version “Removable Bars”).
- Slip rings (not part of the delivery) are only required for particular applications, e.g. if a turntable is used.

Caution:

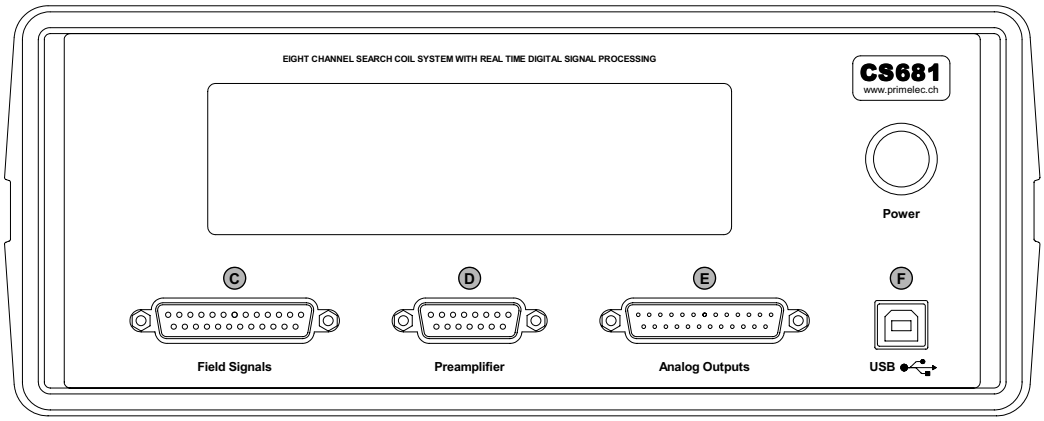
- Read chapter “1.0 Important Safety Instructions“ before wiring and using the system
- Refer system wiring to qualified personnel only
- Turn the system power off to wire the system

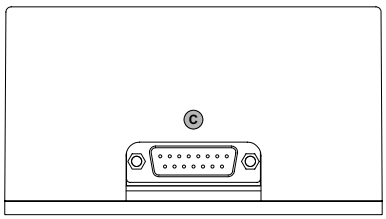
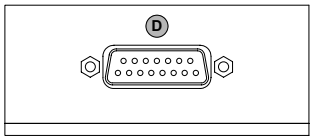
3.2 Main Unit (Rear Panel)



(A)	**Line Voltage Indicator** ***Caution:*** Before any wiring, check the correct setting of the line voltage selector! The indicated value must meet the line voltage of the country of use! See “4.3.2 Connectors and Control Elements” for further details.
(B)	**Power Input** Use the delivered power cord to connect the system to a power source (line voltage either 115 VAC / 60 Hz or 230 VAC / 50 Hz, see above). Use only a power cord certified for the country of use.

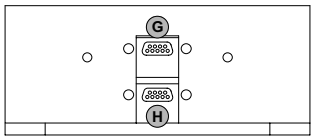
3.3 Main Unit (Front Panel)



C	**Field Signals** Note that this connector also carries the DC power signals used in conjunction with the optional version “Coil Frame with Removable Bars”. If you choosed this option, the delivered cable is 4 x 2 twisted pairs, otherwise 3 x 2 twisted pairs. Use the delivered cable to connect the matching-box of the coil frame. Cable Type: 25 contacts pin connector D-SUB / 15 contacts socket connector D-SUB  Matching-Box
D	**Preamplifier** Use the delivered cable to connect the preamplifier. Cable Type: 15 contacts pin connector D-SUB / 15 contacts pin connector D-SUB  Preamplifier
E	**Analog Outputs** (optional) This connector carries the analog output signals of the system. An external data acquisition system (e.g. an analog data acquisition board for a PC) may be used to capture the analog output signals from the system. You may use the delivered connector (25 contacts socket connector D-SUB) for wiring. For connector pinout details see Appendix, “Pin Numbering and Signal Assignments”.

Ⓕ	**USB** (optional) The system's USB interface continuously transmits the measuring data and may also be used to control the system. Use the delivered cable (USB Type A connector / USB Type B connector) to connect an external computer to this connector. Note: The delivered software must be installed before the system is connected for the first time to an USB port of the computer. See "4.9.1 Software Installation" for further details.

3.4 Search Coils



Preamplifier Front Panel, flange removed

To achieve optimal shielding against stray pick-up of unwanted signals, the two connectors for the search coils at the front panel of the preamplifier are covered by a screw-on flange. To gain access to these connectors, the flange must be removed. See “4.6.3 Handling” for further details.

G	**Search Coils (odd Channels)** Use the delivered connector (9 contacts pin connector MICRO-T) to wire the search coil(s). Note: This connector carries the input signals of the channels 1, 3, 5 and 7. Depending on the application, up to four search coils may be connected to this connector. For connector pinout details see Appendix, “Pin Numbering and Signal Assignments”.
H	**Search Coils (even Channels)** Use the delivered connector (9 contacts pin connector MICRO-T) to wire the search coil(s). Note: This connector carries the input signals of the channels 2, 4, 6 and 8. Depending on the application, up to four search coils may be connected to this connector. For connector pinout details see Appendix, “Pin Numbering and Signal Assignments”.

4.0 System Description

4.1 Measuring Principle

The magnetic field search coil technique introduced by Robinson [1] has become the most commonly used method for quantitative studies of eye and head movements in man and in experimental animals. A coil frame is used to generate an AC magnetic field. The coil frame consists of two or three field coils arranged in space quadrature, which are driven by field signals of different frequencies. The resulting magnetic field induces a voltage in a search coil placed in the coil frame. The spectral components of the field frequencies in the search coil signal are proportional to the sine of the horizontal and vertical angular displacements of the search coil relative to the coil frame.

Traditional search coil systems use analog electronics or digital lock-in amplifiers to demodulate the search coil signal with respect to the magnetic field directions, which cause noise-, phase-, drift- and latency problems. Additional analog to digital converters and a computer are usually used to capture the demodulated search coil signal and to calculate the angular orientation of the search coil. The inherent problems of this approach result in a limited system performance and require fairly complex system adjustments by the operator.

The CS681 uses an other approach to demodulate the search coil signal. The spectral components of the field frequencies are obtained by calculating the Fast Fourier Transformation (FFT) of the digitized search coil signal in real-time. This technique was introduced by Primelec in 1999 and successfully implemented in our Angle-Meter NT, the previous model of the CS681.

Three digitally synthesized sine wave signals of different frequencies are applied to the coil frame to generate the AC magnetic field, which induces a signal in a search coil. In order to avoid routing the susceptible search coil signals over a long distance, the CS681 comes with an external preamplifier. The preamplifier contains eight amplifiers, each with ultra low noise input stage and digital programmable gain. The inputs of the amplifiers are transformer-coupled for galvanic isolation between the search coils and the system. The outputs of the eight amplifiers are time-multiplexed by two 4:1 analog multiplexers. To achieve optimum noise immunity, the two output signals of the analog multiplexers are buffered and differentially transmitted to the main unit.

The main unit comes with two high speed analog to digital converters to digitize the preprocessed signals of two search coils in parallel. The use of a high performance digital signal processor (DSP) and a field programmable gate array (FPGA) makes it possible to compute the FFT and the subsequent trigonometric calculations in real-time. The complete data processing for two search coils takes less than 125 us, affording a high-speed output data rate of

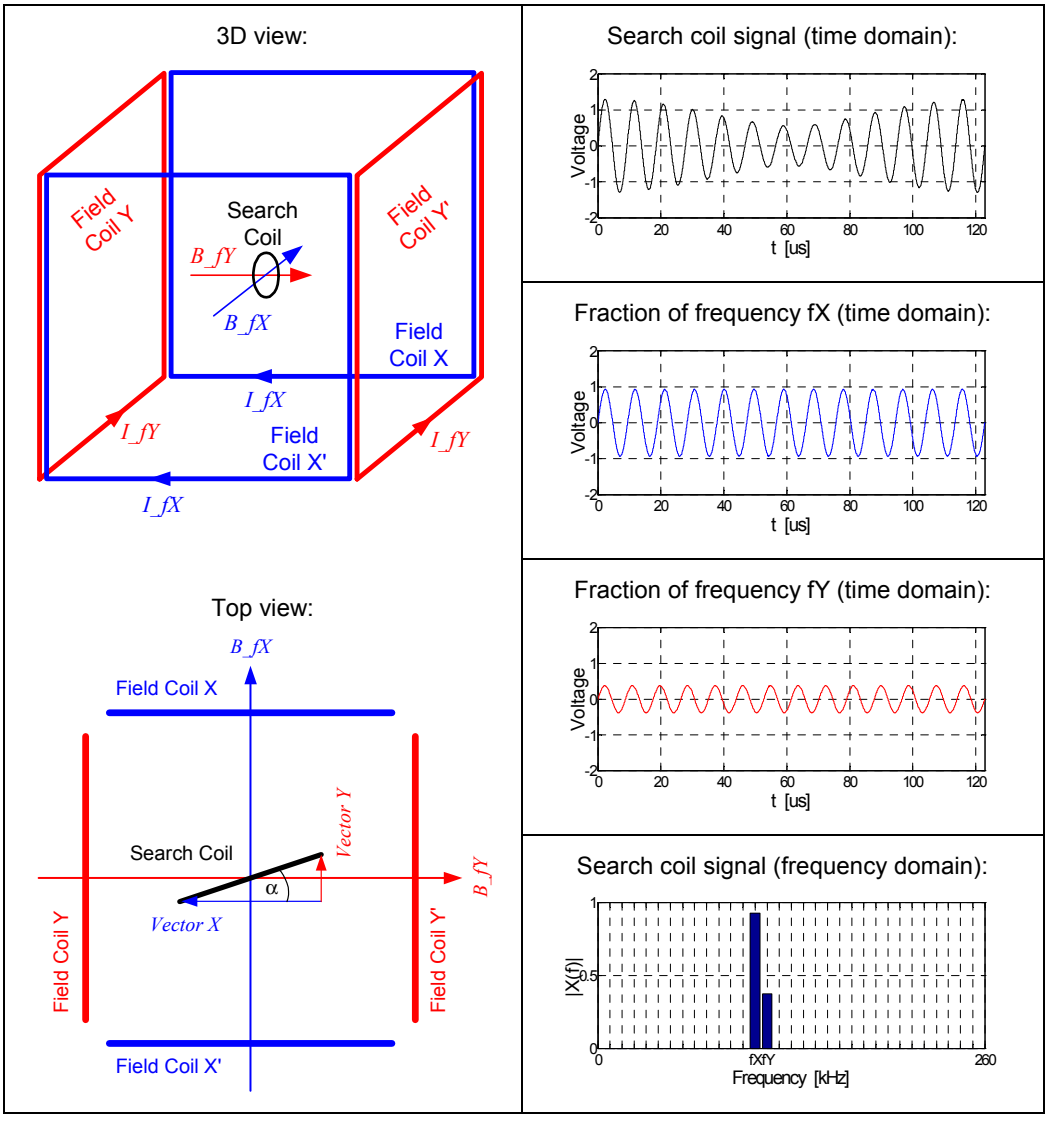
[1] Robinson D.A. (1963), A method of measuring eye movements using a scleral search coil in a magnetic field, IEEE Transactions on Biomedical Engineering 10: 137-145

up to 8000 readings per second and a latency of only 500 us. The output data is available over the USB interface and as analog signals over the integrated digital to analog converters.

This approach provides remarkable advantages compared to traditional systems. Very high system performance is achieved, linear angular output data for the horizontal and vertical plane is provided and almost no system adjustments are required by the operator.

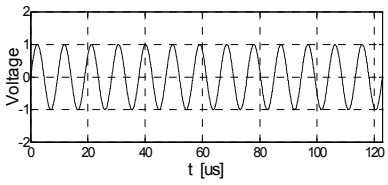
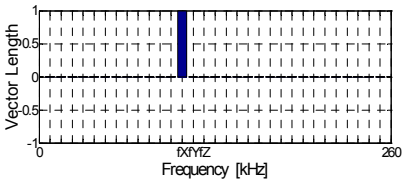
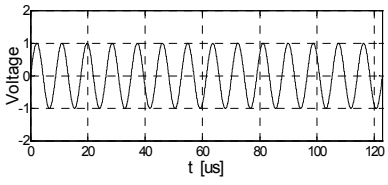
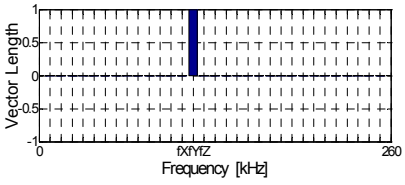
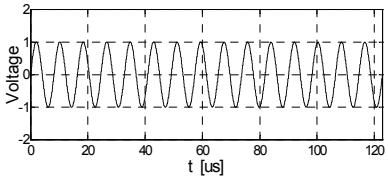
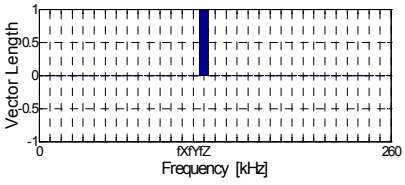
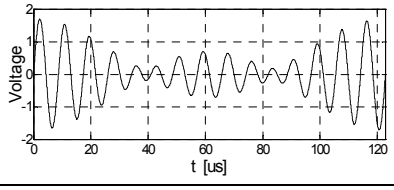
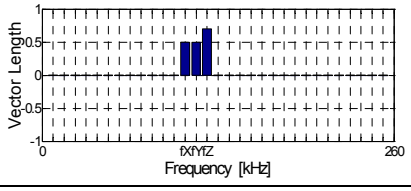
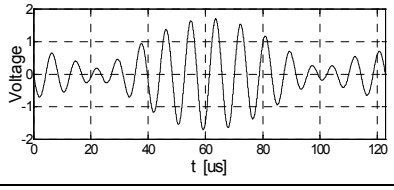
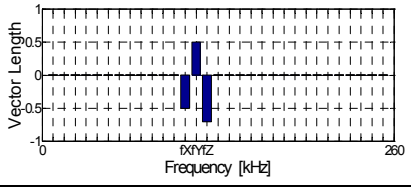
The pictures on the left in the table below schematically depict a search coil, placed in a AC magnetic field B generated by the currents I in the field coils X-X' and Y-Y'. For simplicity, a coil frame with only two field coils is shown.

The spectral components of the two field frequencies fX and fY in the resulting search coil signal are proportional to the sine of the angular displacement of the search coil relative to the coil frame (Vector X and Y, angle α).



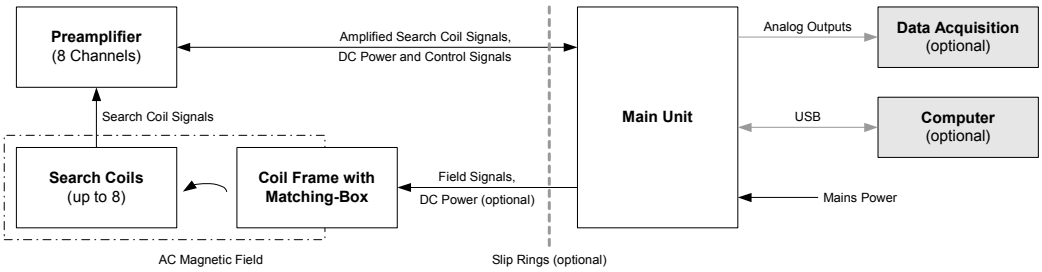
The CS681 uses three field signals of different frequencies, which are applied to three field coils to generate the AC magnetic field. The spectral components of the field frequencies in the induced search coil signal are obtained by computing the Fast Fourier Transformation (FFT) of the digitized search coil signal. The resulting frequency components of the field signals fX (X-axis), fY (Y-axis) and fZ (Z-axis) are used to calculate angle α (horizontal plane) and angle β (vertical plane) by trigonometric calculations.

The table below depicts some examples to illustrate the correlation between the angular orientation of the search coil placed in the AC magnetic field (angles α and β), the resulting induced search coil signal (time domain) and the vector lengths from the FFT (frequency domain), where the vector lengths are scaled to ± 1 for better clarity.

α	β	Time Domain	Frequency Domain
0°	180°		
90°	180°		
90°	270°		
45°	225°		
135°	135°		

4.2 System Overview

The coil system CS681 basically consists of the following components:



Optional components:

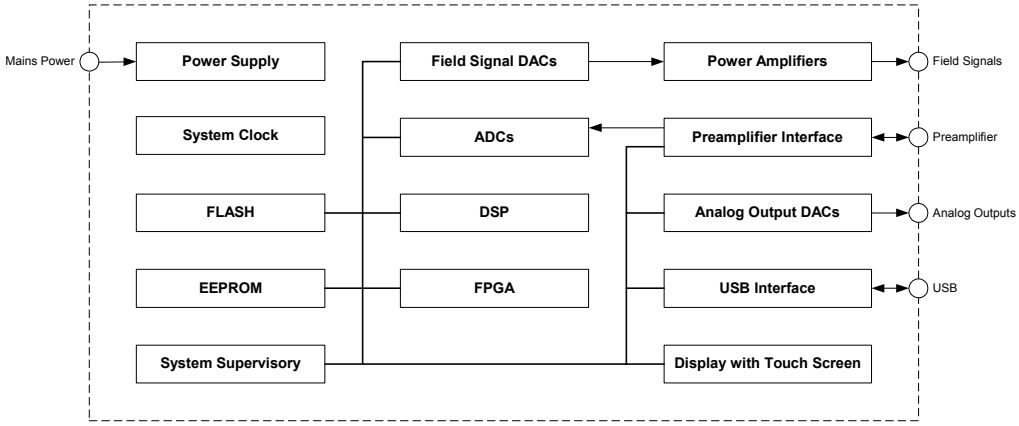
- DC power for the matching-box is only required in conjunction with the optional version “Coil Frame with Removable Bars”.
- Slip rings are only required for particular applications, e.g. if a turntable is used.
- The use of an external data acquisition system is optional, see “4.8 External Data Acquisition ” for further details.
- The use of an external computer is optional, see “4.9 External Computer” for further details.

The following chapters describe each component of the system.

4.3 Main Unit

4.3.1 Functional Description

The main unit of the CS681 basically contains the following functional blocks:



- **Power Supply**
  The power supply may be operated either with 115 VACRMS or with 230 VACRMS line voltage (50Hz to 60Hz). The maximum power consumption is 250 VA.
- **System Clock**
  The internal system clock is generated by a quartz oscillator.

- **Field Signal DACs**
  The field signal DACs (digital to analog converters) digitally synthesizes six sine wave signals in conjunction with the data from the FPGA:
  Field signal X1, X2, Y1, Y2, Z1 and Z2. The field signals have different frequencies:

  fX = 105.794 kHz, fY = 113.932 kHz, fZ = 122.070 kHz.

  Note: Other frequencies may be generated. Ask Primelec for further details.

  The amplitudes of the generated signals are digitally programmable. The polarity of each signal may be reversed.

  The phasing of the field signals X2, Y2 and Z2 relative to the respective field signals X1, Y1 and Z1 is user selectable. The field signals X2, Y2 and Z2 are reserved for future use, i.e. these field signals are not used for standard applications.

- **Power Amplifiers**
  The power amplifiers boost the generated field signals in order to drive the coil frame. The power amplifiers have differential outputs to provide optimal noise immunity.

- **Preamplifier Interface**
  The preamplifier interface receives the amplified search coil signals from the preamplifier and receives / transmits control signals from / to the preamplifier. The preamplifier interface also provides the DC power required by the preamplifier.

- **ADCs**
  The ADCs (analog to digital converters) digitize the amplified search coil signals from the preamplifier interface.
  Note: The main unit contains two ADCs. The first ADC converts the time-multiplexed search coil signals of the odd channels (i.e. channel 1, 3, 5 and 7), the second ADC converts the time-multiplexed search coil signals of the even channels (i.e. channel 2, 4, 6 and 8).

- **DSP**
  The DSP (digital signal processor) processes the data from the ADCs, computes the measuring data and controls the system.

  Note: The firmware of the DSP is upgradeable by the system administrator to allow the upgrade of the system on location if future versions of the firmware are available.

- **FPGA**
  The FPGA (field programmable gate array) implements various hardware functionalities of the main unit.

  Note: The firmware of the FPGA is upgradeable by the system administrator to allow the upgrade of the system on location if future versions of the firmware are available.

- **FLASH**
  The FLASH-Memory holds the upgradeable firmware of the DSP and the FPGA.
- **EEPROM**
  The EEPROM holds the configuration data of the system.
- **System Supervisory**
  The internal supply voltages and the temperature inside of the cabinet of the main unit are constantly monitored.
- **Analog Output DACs**
  The analog output DACs (digital to analog converters) convert the computed measuring data from the DSP to analog signals. The analog outputs may be used in conjunction with an external data acquisition system.

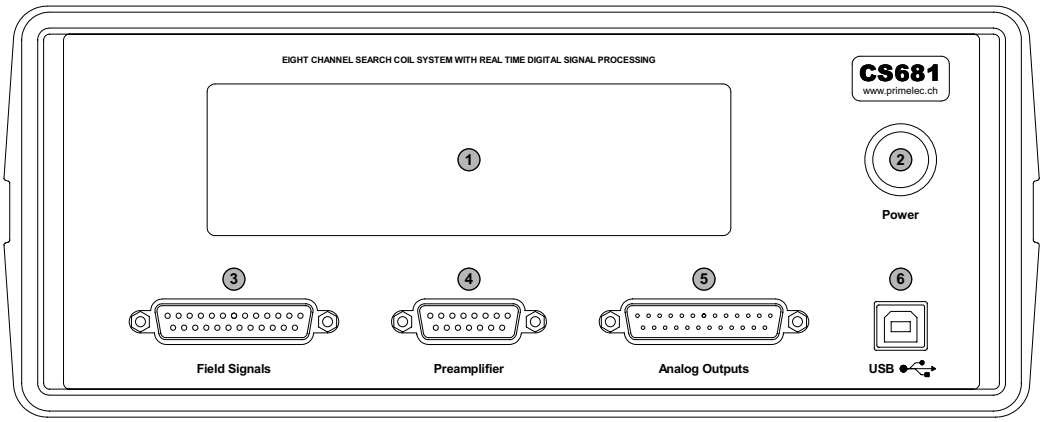
  The format and the voltage swing of the analog outputs are selectable by the operator.
- **USB Interface**
  The USB 1.1 / 2.0 interface continuously transmits the measuring data and receives / transmits control data.
- **Display with Touch Screen**
  The graphical display with touch screen allows a user friendly, menu controlled operation of the system.

  Note: The firmware of the display controller is upgradeable by the system administrator to allow the upgrade of the system on location if future versions of the firmware are available.

4.3.2 Connectors and Control Elements

Front Panel

This section describes the connectors and control elements on the front panel of the main unit.

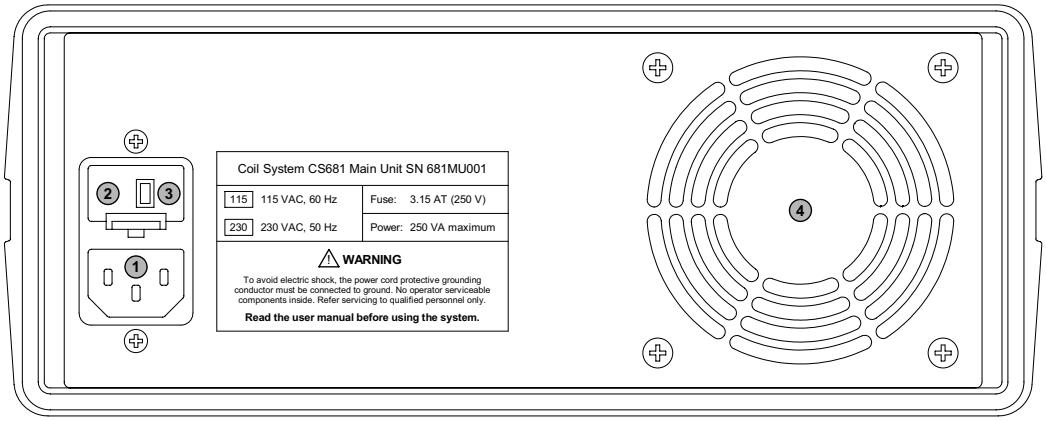


1	**Display with Touch Screen** The display is filled with many details about the current state and settings of the system. See “5.1 Display Area” for further details. The touch screen of the display responds to the pressure of a finger or a fingernail. This allows a user friendly, menu controlled operation of the system. See “5.2 Menu System” for further details. ***Caution:*** • Exercise care in using the touch-sensitive screen. It is designed for finger-pressure only. Do not touch with pen, pencil, or any sharp object. Inappropriate handling may scratch the protective sheet of the touch screen! • Use a damp, soft and lint-free cloth to clean the front panel. Never use any cleansing agents or solvents!
2	**Mains Power Switch** Use the power switch to turn the system power on or off. ***Caution:*** Check the correct setting of the line voltage selector before turning the system power on! See the description of the main unit’s rear panel for further details.

③	**Connector 'Field Signals'** 25 contacts socket connector D-SUB This connector carries the signals used to generate the magnetic field as well as the DC power signals used in conjunction with the optional version "Coil Frame with Removable Bars". Use the delivered cable to connect the matching-box of the coil frame to this connector. For connector pinout details see Appendix, "Pin Numbering and Signal Assignments". Note: Should the coil frame be operated on a turntable, at least 7 slip ring contacts are required for wiring. The option "Coil Frame with Removable Bars" requires two additional slip ring contacts for wiring the DC power signals. See Appendix, "Slip Ring Wiring" for further details.
④	**Connector 'Preamplifier'** 15 contacts socket connector D-SUB This connector carries the interface signals from / to the preamplifier. Use the delivered cable to connect the preamplifier to this connector. For connector pinout details see Appendix, "Pin Numbering and Signal Assignments". Note: Should the preamplifier be operated on a turntable, at least 11 slip ring contacts are required for wiring. See Appendix, "Slip Ring Wiring" for further details.
⑤	**Connector 'Analog Outputs'** 25 contacts pin connector D-SUB This connector carries the analog output signals of the system. You may use an external data acquisition system (e.g. an analog data acquisition board for a PC) to capture the analog output signals from the system. See "5.7 Using the Analog Outputs" for further details. For connector pinout details see Appendix, "Pin Numbering and Signal Assignments".
⑥	**Connector 'USB'** 4 contacts USB Type B connector This connector carries the USB interface signals. The system's USB interface continuously transmits the measuring data and may also be used to control the system. See "5.8 Using the USB Interface" for further details. For connector pinout details see Appendix, "Pin Numbering and Signal Assignments".

Rear Panel

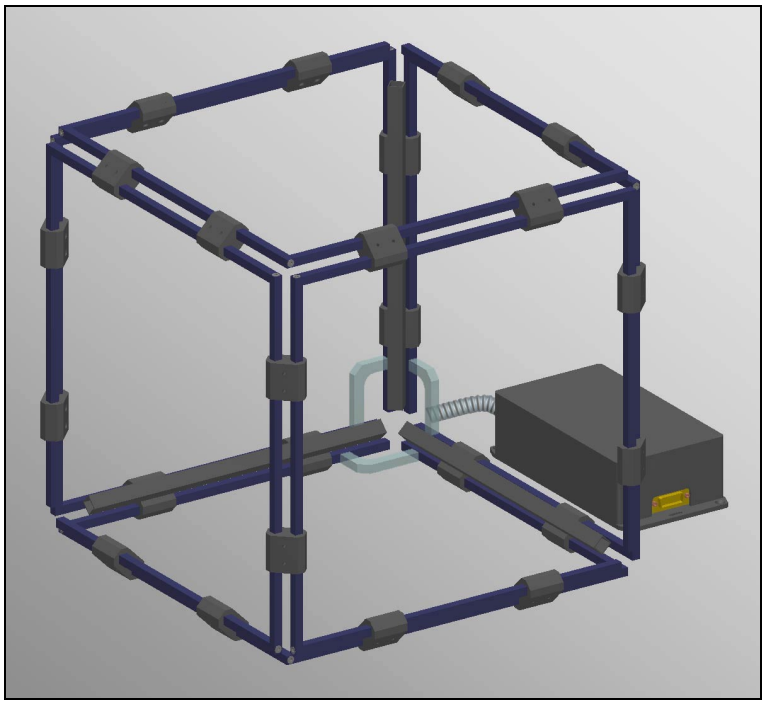
This section describes the connectors and control elements on the rear panel of the main unit.



1	**Power Input** Use the delivered power cord to connect the system to a power source. Use only the power cord certified for the country of use. The system is grounded through the grounding conductor of the power cord. ***Caution:*** The setting of the line voltage selector (see below) must meet the voltage of the power source! Use a power source that delivers either 115 VACRMS or 230 VACRMS (50 Hz to 60 Hz).
2	**Drawer with Fuse Holder and Line Voltage Selector** The drawer contains the fuses and the line voltage selector. The line voltage selector is used to set the system's operating voltage to the applied line voltage. To change the setting of the line voltage selector, remove the drawer from the element. Extract the line voltage selector from the drawer and insert it such that the correct setting is indicated in the line voltage indicator. ***Caution:*** • Check the correct setting of the line voltage selector before connecting the power cord! • Remove the power cord before handling the line voltage selector! • Use only the fuse type and rating specified for the system! • Refer servicing to qualified personnel only!
3	**Line Voltage Indicator** Indicates the actual setting of the line voltage selector (see above).

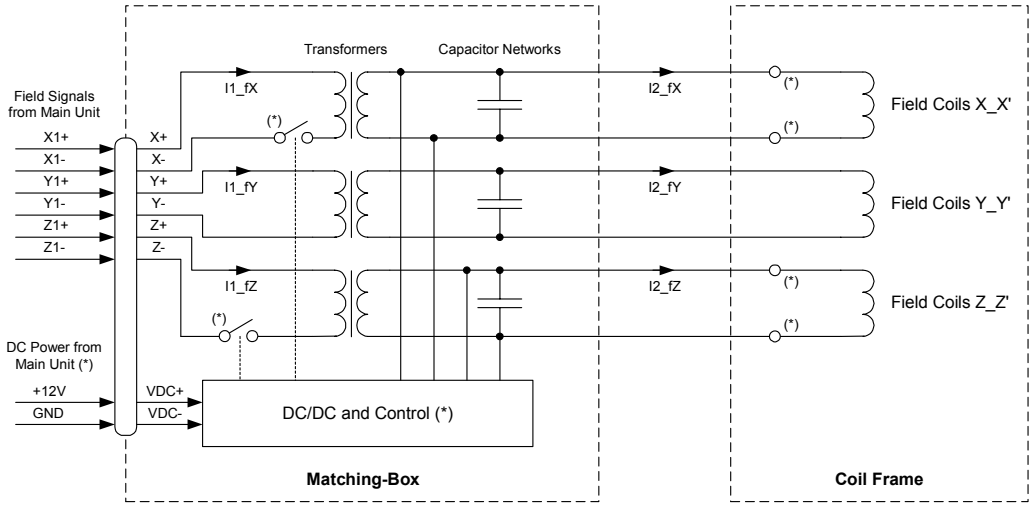
④	**Fan** The fan is used for system ventilation. ***Caution:*** Always ensure proper ventilation! Always keep clean the fan and the ventilation slots. The distance from the rear panel to surrounding objects should be at least 20 cm to ensure proper ventilation.

4.4 Coil Frame with Matching-Box



4.4.1 Functional Description

The coil frame with matching-box of the CS681 basically contains the following functional blocks:



Note:

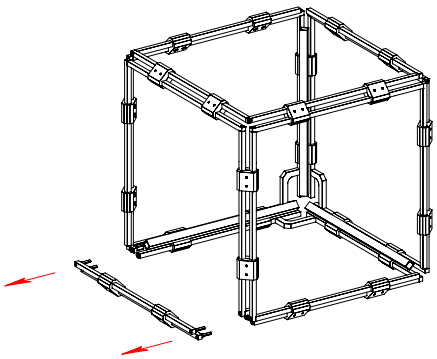
The components marked with an asterisk are present only in the optional version “Coil Frame with Removable Bars”.

- **Matching-Box**
  The differential field signals X, Y and Z from the main unit are applied to the matching-box. Within the matching-box, the field signals are applied via three transformers to three capacitor networks, which build the capacitive part of three parallel resonance circuits. The capacitor networks are tuned at the factory such that their resonance frequencies meet the field frequencies fX, fY and fZ respectively.

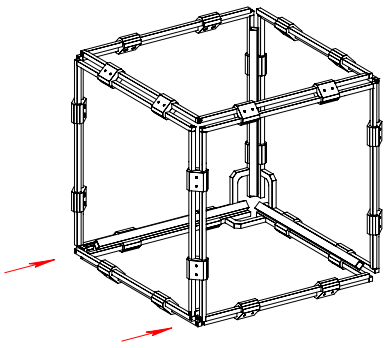
  If you choosed the option “Removable Bars” for the coil frame, the matching-box contains the components in the section “DC/DC and Control” to disconnect the field signals X and / or Z if the respective bars are removed from the coil frame.

- **Coil Frame**
  The coil frame is used to generate the magnetic field used by the system. The coil frame consist of three pairs of one-turn field coils, arranged as a cube, which build the inductive part of the parallel resonance circuits. The resonance currents in the field coils (I2_fX, I2_fY and I2_fZ) generate the magnetic field (fX for the X-axis, fY for the Y-axis and fZ for the Z-axis). Thanks to the use of parallel resonance circuits, the currents of the field signals I1_fX, I1_fY and I1_fZ are only a fraction of the resulting resonance currents of the field coils.

- **Coil Frame option “Removable Bars”**
  The optional available "Removable Bars" allow the effortless removing of one bar per coil X and Z respectively to open the coil frame at the bottom. The removable bars are simply plugged into the frame such that no tools are required to open / close the coil frame at the bottom.



1.) Pull out the removable bars to open the coil frame and insert large objects into the coil frame, e.g. a primate chair



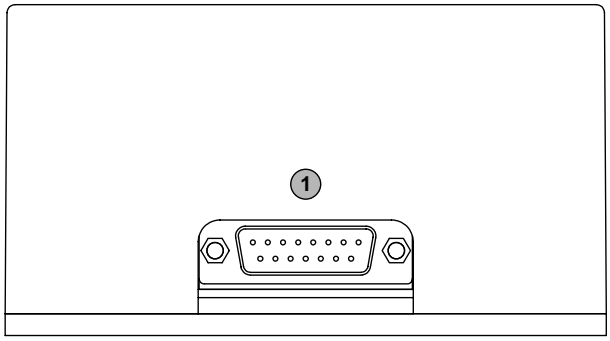
2.) Plug in the removable bars to close the coil frame when ready to run measurements

Turn the system power off before handling the removable bars. Pay attention to move the bars orthogonal to the respective socket connectors of the coil frame to avoid mechanical damage.

4.4.2 Connectors

Matching-Box

This section describes the connector on the front panel of the matching-box.



1	**Connector 'Field Signals'** 15 contacts pin connector D-SUB This connector carries the signals used to generate the magnetic field as well as the DC power signals used in conjunction with the optional version "Coil Frame with Removable Bars". Use the delivered cable to connect the main unit to this connector. For connector pinout details see Appendix, "Pin Numbering and Signal Assignments". Note: Should the coil frame be operated on a turntable, at least 7 slip ring contacts are required for wiring the field signals. The option "Coil Frame with Removable Bars" requires two additional slip ring contacts for wiring the DC power signals. See Appendix, "Slip Ring Wiring" for further details. ***Caution:*** Do not attach or remove the cable whilst the system is operating! Turn the system power off to attach or remove the cable.

4.4.3 Handling

This section describes the handling of the coil frame.

The coil frame may be demounted, which may be helpful for the mounting of a particular setup. Ask Primelec for further details.

The amplitudes of the field signals are tuned at the factory to achieve the specified flux density and an optimal homogeneity of the AC magnetic field at the 3D-centre of the coil frame. Therefore the used search coils should be operated as close as any possible to the 3D-centre of the coil frame to achieve optimal system linearity.

The operator should never change the respective amplitudes of the field signals X, Y or Z because of this would change the factory tuning of the magnetic field. To reduce the magnetic field strength, e.g. if extremely large search coils are used or to turn off the magnetic field, the operator may attenuate the tuned field signals in steps of 10% down to zero. See “5.3.10 Field Signals Magnitude” for further details.

As mentioned above, the amplitudes of the field signals are tuned at the factory. However, if required for any reason, the amplitude of the field signals may be adjusted individually by the system administrator. See “5.3.11 Field Signal X / Y / Z” for further details.

The polarity of each field signal may be reversed by the system administrator. This may be useful to reverse the polarity of the field in the respective axis without the need for changing the physical connection polarity of the coil frame. A reversed field polarity results in reversed polarity in the respective axis of all search coils. See “5.3.13 Field Signal Polarity X / Y / Z” for further details.

If you choosed the option “Removable Bars” for the coil frame, pay attention to move the bars orthogonal to the respective socket connectors of the coil frame to avoid mechanical damage whilst handling the removable bars.

Note:

An optimal quality of the magnetic field is essential to achieve high system performance . To avoid problems see “6.0 System Optimization”.

Caution:

- The signals applied to the coil frame may have hazardous voltage levels! An inappropriate application (touching the conductors or the coil frame, capacitive and / or inductive couplings etc.) can come for injuries to health. Do not touch any exposed connections and components when power is present.

- The coil frame of the CS681 generates an AC magnetic field which can lead to injury to health! Capacitive and inductive coupling onto organisms and devices sensitive in this regard must be considered.
- Do never disconnect the coil frame from the matching-box whilst the system is operating! This results in capacitive loading of the system's power amplifiers, which may overheat and / or destroy the power amplifiers.
- If you choosed the option "Removable Bars" for the coil frame, do never pull out / plug in the removable bars whilst the system is operating! Turn the system power off before handling the removable bars.

4.4.4 Coordinate System

Typically, two types of Cartesian coordinate systems are used: left-handed and right-handed. In both coordinate systems, the positive X-axis points to the right, and the positive Y-axis points up. You can remember which direction the positive Z-axis points by pointing the fingers of either your left or right hand in the positive X-direction and curling them into the positive Y-direction. The direction your thumb points, either toward or away from you, is the direction that the positive Z-axis points for that coordinate system.

The table below shows these two coordinate systems and the correlation of the axes to the system's field frequencies.

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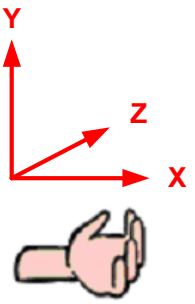
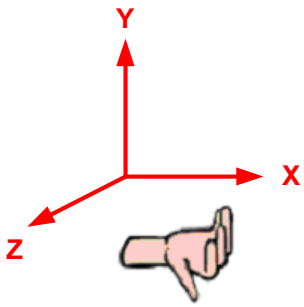
<tr><th>Left-Handed Cartesian Coordinates</th><th>Right-Handed Cartesian Coordinates</th></tr>
<tr><td> 
</td><td> 
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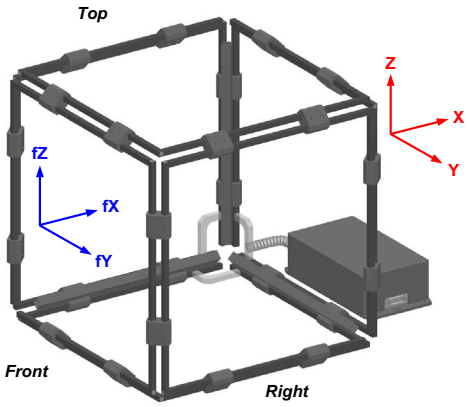
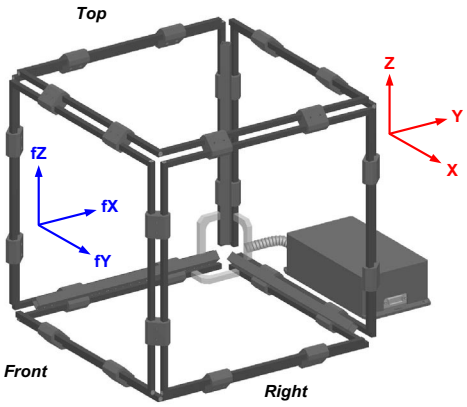
<tr><td> 
</td><td> 
</td></tr>
<tr><td>
<table>
<tr><th>Axis</th><th>Correlated Field Frequency</th></tr>
<tr><td>X</td><td>fX</td></tr>
<tr><td>Y</td><td>fY</td></tr>
<tr><td>Z</td><td>fZ</td></tr>
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<table>
<tr><th>Axis</th><th>Correlated Field Frequency</th></tr>
<tr><td>X</td><td>fY</td></tr>
<tr><td>Y</td><td>fX</td></tr>
<tr><td>Z</td><td>fZ</td></tr>
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4.5 Third Party Coil Frame

Primelec strongly recommends the use of our coil frame to achieve highest system performance. However, read this section if you nevertheless plan to use a third party coil frame.

Exclusion of warranty and liability:
Using a third party coil frame will constitute a breach of warranty. In addition, Primelec don't warrants the reliability, accuracy or functionality of the system if a third party coil frame is used.
In no event shall Primelec, its employees or its suppliers be liable for any injury, loss, claim or consequential damages of any kind.

Precautions:

- The use of a third party coil frame presumes complex installation and adjustment processes. Only qualified personnel may be involved to this, and only after becoming familiar with the concerning standards, regulations and the system's functional principle.
- The system's field signals may achieve hazardous voltage levels. An inappropriate application (touching the conductors or the coil frames, capacitive and / or inductive couplings etc.) can come for injuries to health.
- Improper system handling or the use of inappropriate settings during installation, adjustment or operation of a third party coil frame may cause serious harm to the system. Using a third party coil frame will constitute a breach of warranty.

4.5.1 The Coil Frame

The coil frame should consist of three field coils (X-, Y- and Z-coil), each with two windings. Depending on the dimension of the coil frame, the required field coil current (i.e. the resonance current) is up to 20 A. This must be considered for the evaluation of the material used for the field coils and the wiring. Aluminium bars (cross section 8 x 8 mm) may be used for the field coils. Copper wires with at least 1.5 mm^2 are suggested for the wiring. The connection wires must be tight twisted in order to prevent radiation of stray fields and to achieve a high Q-Factor of the resonance circuits.

4.5.2 The Matching-Box

Transformers

The matching-box contains application specific transformers. The turn ratio depends on the dimension of the used coil frame. Coil frames below 50 cm have 1 : 1 transformers, coil frames between 50 cm and 70 cm have 1 : 1.5 transformers in order to achieve higher field voltages. The use of coil frames larger than 70 cm is not recommended.

The transformers are based on ferrite toroids with a rather large diameter to ease the winding process (e.g. EPCOS series N30, B64290L0674X830). The primary winding has 30 turns, the number of turns of the secondary winding depends on the size of the coil frame: 30 turns (coil frame up to 50 cm) or 45 turns (coil frame 50 … 70 cm). Use insulated copper wire, diameter 0.5 mm, for both windings.

Resonance Circuit Tuning

Three sets of capacitors in the matching-box are connected in parallel with the respective field coils (LC resonance circuits). The required total capacitance per resonance circuit depends on the frequency of the applied field signal and the total inductance of the coil. The total inductance of the coil varies depending on the size of the field coils and the wiring. Due to the effect of the wiring on the resulting total inductance, the tuning of the resonance circuits assumes a completely wired coil frame, i.e. the connection wires must have final lengths and tight twisting.

Adjust the total capacitance of each set of capacitors to achieve resonance at the specified frequencies. Get started by quantifying the total inductance of the field coils. The measured inductance (L) is used to estimate the required total capacitance (C) for each resonance circuit:

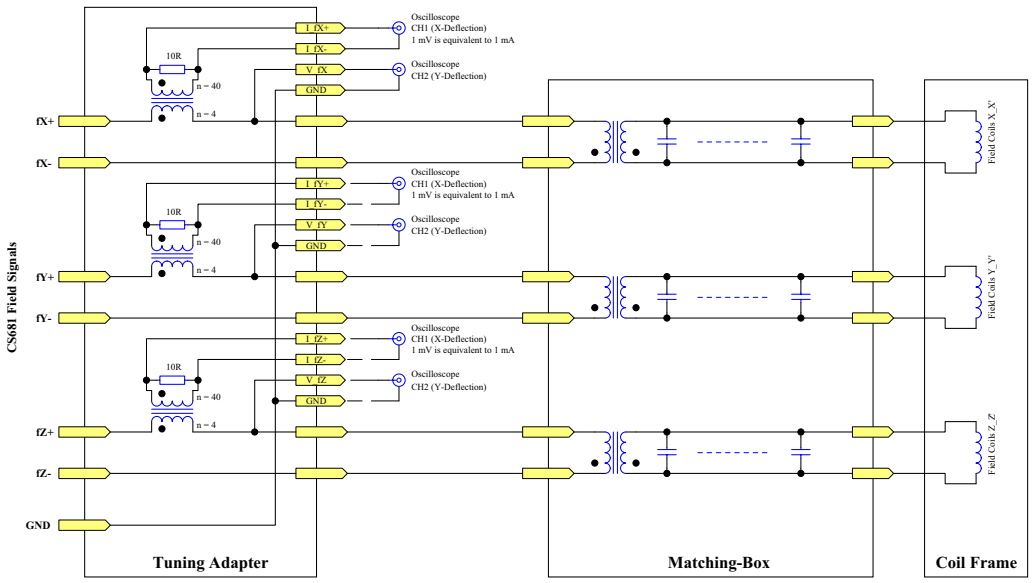
$C = ((1 / 2 \text{ pi } f_R)^2) / L$

X-Axis: f_R = 105.794 kHz, Y-Axis: f_R = 113.932 kHz, Z-Axis: f_R = 122.070 kHz

Note: In order to be able to operate up to three systems close together (e.g. in the same lab), other frequencies for fX, fY and fZ may be used for the field signals. Ask Primelec for further details.

Use metallized polypropylene film capacitors (e.g. EPCOS, series B3265x) for the resonance circuits to achieve a high Q-Factor of the resonance circuits. Tune the resonance circuits one by one. Start in each case with a capacitance value which is slightly lower than estimated and tune the resonance circuits by adding capacitors in parallel until the circuits are exactly in resonance at the specified frequencies (i.e. zero phase lag between the field signal voltage and the field signal current).

The figure below depicts an appropriate adapter to measure the phase lag with an oscilloscope (Mode X-Y).



Precautions:

- An exactly tuned resonance circuit behaves as an Ohm resistive load for the system's power amplifier. Whilst the resonance frequency of the resonance circuits not meet the frequency of the applied signal, the power amplifier must drive a capacitive or inductive load. Therefore use low field voltages (below 1 V RMS) during the tuning process to prevent overloading and / or damaging the power amplifier.
- Mismatched resonance circuits may overheat and / or damage the power amplifiers and / or will cause phase errors and drift on the system's measuring data outputs.

4.5.3 Field Signals Tuning

Once the resonance circuits are tuned exactly, the amplitude of the field signals must be tuned to calibrate the generated magnetic field. The correct amplitude of the field signals depends on the size of the coil frame, the used transformers, the Q-Factor of the resonance circuits and the frequency of the respective field signal.

The amplitude of the field signals is set over the USB interface by using the delivered application software (see “5.8 Using the USB Interface” for further details). See also “5.3.11 Field Signal X / Y / Z“ for additional information.

Precautions:

- The field signals can achieve hazardous voltage levels, precautions in this regard must be considered.
- Inappropriate settings of the field signals may overheat and / or damage the power amplifiers and / or will cause inaccurate output data.

Coarse Tuning of the Field Signals

Adjust the amplitude of the three field signals to achieve the specified magnetic flux densities at the 3D-center of the coil frame: 11.34 uT (105.794 kHz, X-axis), 10.53 uT (113.932 kHz, Y-axis) and 9.83 uT (122.070 kHz, Z-axis). Tune the amplitude of the field signals one by one until the specified flux density is achieved for each axis. Do not overload the power amplifiers (max. 350 mA output current per channel with Ohm resistive load, i.e. exactly tuned resonance circuits assumed).

Fine Tuning of the Field Signals

A fine tuning of the amplitude of the field signals is recommended to optimize the homogeneity of the magnetic field at the 3D-center of the coil frame. Adjust the amplitude of the field signals Y and Z until the induced voltage in a given search coil, which is orthogonal aligned at the 3D-centre of the coil frame, is identical in all three axes.

The table shows a step-by-step guidance for the fine tuning of the field signals:

Step	Instruction
1.	**Preparation**: • Wire the system as described in this User Manual • Connect a computer to the USB interface of the CS681 The delivered application software and the driver for the CS681 must already be installed on the used computer
2.	Turn the system power on and use the **following settings** for the CS681: • Field Signals: 100% • Gain Correction: Disabled • Offset Correction: Disabled • Low Pass Filter: Disabled • System Mode: Normal
3.	**Place a search coil at the 3D-center** of the coil frame and connect it to **channel 1** of the preamplifier. Any search coil which meets the specification (see technical data) may be used. **Do not change the position of the search coil within the coil frame during the following steps**, i.e. vary only the angular orientation of the search coil if prompted.
4.	Use the delivered application software to set an **adequate value for the preamplifier gain of channel 1**. Preferably you should use the 'Automatic Tuning' for the 'Preamplifier Gain' of channel 1 to evaluate an adequate value. The Level Indicator of the display must indicate a level within the operational range for channel 1. **Once set to an adequate value, do not change the gain of the preamplifier during the following steps**.
5.	**Turn the search coil vertically and / or horizontally to meet the following conditions:** • The length of vector **X** of CH 1 is as **large** as achievable • The length of vector **Y** of CH 1 is as **small** as achievable (preferably zero) • The length of vector **Z** of CH 1 is as **small** as achievable (preferably zero) Fix the search coil once it has an angular orientation such that these conditions are meet. The search coil must now have an orthogonal orientation relative to the coil frame axis X, and a parallel orientation relative to the coil frame axes Y and Z. **Write down the length of vector X of CH 1** (**'VectLenX_Max'**) for later use in steps 6 and 7.

Continued on next page…

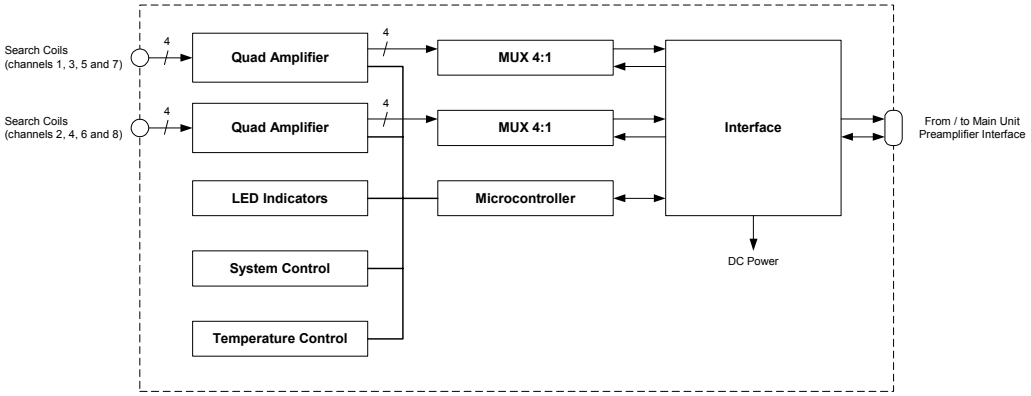
…continuation:

Step	Instruction
6.	**Turn the search coil vertically and / or horizontally to meet the following conditions:** • The length of vector **X** of CH 1 is as **small** as achievable (preferably zero) • The length of vector **Y** of CH 1 is as **large** as achievable • The length of vector **Z** of CH 1 is as **small** as achievable (preferably zero) Fix the search coil once it has an angular orientation such that these conditions are meet. The search coil must now have an orthogonal orientation relative to the coil frame axis Y, and a parallel orientation relative to the coil frame axes X and Z. Use the delivered application software to increase or decrease the amplitude of the **field signal Y** until the length of vector **Y** of CH 1 meets **'VectLenX_Max'** (see step 5).
7.	**Turn the search coil vertically and / or horizontally to meet the following conditions:** • The length of vector **X** of CH 1 is as **small** as achievable (preferably zero) • The length of vector **Y** of CH 1 is as **small** as achievable (preferably zero) • The length of vector **Z** of CH 1 is as **large** as achievable Fix the search coil once it has an angular orientation such that these conditions are meet. The search coil must now have an orthogonal orientation relative to the coil frame axis Z, and a parallel orientation relative to the coil frame axes X and Y. Use the delivered application software to increase or decrease the amplitude of the **field signal Z** until the length of vector **Z** of CH 1 meets **'VectLenX_Max'** (see step 5).

4.6 Preamplifier

4.6.1 Functional Description

The preamplifier of the CS681 basically contains the following functional blocks:



- **Quad Amplifiers**
  The preamplifier contains two quad amplifiers, i.e. the preamplifier contains a total of eight amplifiers. The first quad amplifier processes the odd channels (i.e. channel 1, 3, 5 and 7), the second quad amplifier processes the even channels (i.e. channel 2, 4, 6 and 8). Each channel processes the signal from one search coil. Each amplifier features an ultra low noise input stage with digital programmable gain. The gain of each channel must be set to a reasonable value, depending on the characteristics of the connected search coil and the magnitude of the magnetic field. The inputs of the amplifiers are transformer-coupled and therefore the connected search coils are galvanic isolated from the system.
- **MUX 4:1**
  The outputs of each quad amplifier are time multiplexed by a 4:1 analog multiplexer (MUX). The output of the first MUX therefore provides the time multiplexed signals from the channels 1, 3, 5 and 7 (odd channels) and the output of the second MUX provides the time multiplexed signals from the channels 2, 4, 6 and 8 (even channels) to the interface.
- **Interface**
  The interface transmits the amplified, time multiplexed search coil signals to the main unit. The signals are transmitted differential in order to achieve optimal noise immunity.

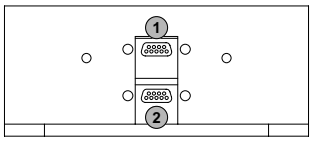
  The interface also receives / transmits the control signals from / to the main unit. In addition, the interface is also conditioning the DC power provided from the main unit.
- **Microcontroller**
  A microcontroller is used to control the preamplifier.

  Note: The firmware of the microcontroller is upgradeable by the system administrator to allow the upgrade of the system on location if future versions of the firmware are available.
- **LED Indicators**
  Four LEDs are used to indicate the state of the preamplifier.
- **System Control**
  The functionality of various components is monitored.
- **Temperature Control**
  The temperature inside of the cabinet of the preamplifier is monitored.

4.6.2 Connectors and LED Indicators

Front Panel

This section describes the connectors on the front panel of the preamplifier.



Preamplifier Front Panel, flange removed

To achieve optimal shielding against stray pick-up of unwanted signals, the two connectors for the search coils at the front panel of the preamplifier are covered by a screw-on flange. To gain access to these connectors, the flange must be removed. See “4.6.3 Handling” for further details.

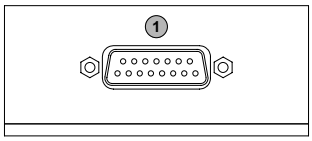
(1)	**Connector ‘Search Coils (Odd Channels)’** 9 contacts socket connector MICRO-T This connector carries the input signals of the channels 1, 3, 5 and 7, i.e. up to four search coils may be connected to this connector. For connector pinout details see Appendix, “Pin Numbering and Signal Assignments”.
(2)	**Connector ‘Search Coils (Even Channels)’** 9 contacts socket connector MICRO-T This connector carries the input signals of the channels 2, 4, 6 and 8, i.e. up to four search coils may be connected to this connector. For connector pinout details see Appendix, “Pin Numbering and Signal Assignments”.

Notes:

- In order to avoid routing the susceptible analog signals of the search coils over long distances, the preamplifier should be placed as near to the used search coils as possible. Therefore, if e.g. a turntable is used, do not route the search coil signals over the slip rings. Instead, route the connections between the preamplifier and the main unit over the slip rings. See the description of the connector ‘Preamplifier’ on the next page.
- See also “4.7 Search Coils“ for further details.

Rear Panel

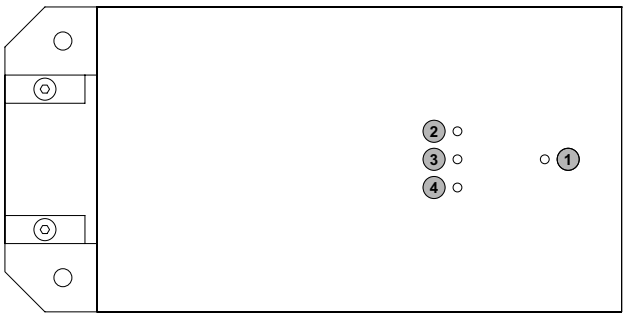
This section describes the connector on the rear panel of the preamplifier.



1	**Connector 'Preamplifier'** 15 contacts socket connector D-SUB This connector carries the interface signals from / to the preamplifier. Use the delivered cable to connect the main unit to this connector. For connector pinout details see Appendix, "Pin Numbering and Signal Assignments". Note: Should the preamplifier be operated on a turntable, the signals of this connector should be routed over the slip rings, at least 11 slip ring contacts are required for wiring. See Appendix, "Slip Ring Wiring" for further details. ***Caution:*** Do not attach or remove the cable whilst the system is operating! Turn the system power off to attach or remove the cable.

Cover

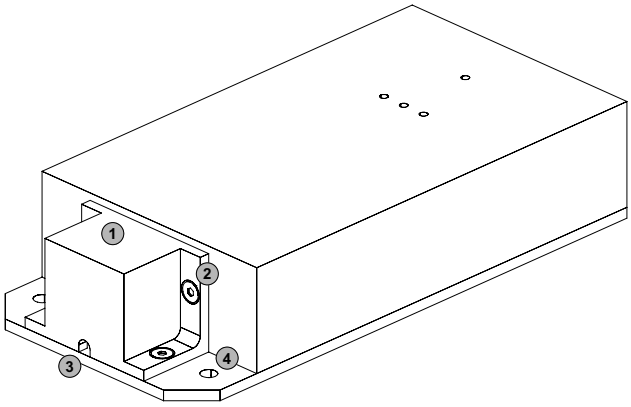
This section describes the LEDs on the cover of the preamplifier.



1	**LED 'PWR'** Blue LED, indicating that the preamplifier is powered.
2	**LED 'TMP'** Red LED, indicating that the maximum tolerable temperature (60°C) inside of the cabinet of the preamplifier is exceeded. Under normal conditions, the temperature inside of the cabinet of the preamplifier is far below the maximum tolerable temperature. ***Caution:*** This LED indicates an error! Immediately turn the system power off if this LED should turn on and contact Primelec for further instructions.
3	**LED 'RXD'** Green LED, indicating that the preamplifier has received control data from the main unit.
4	**LED 'TXD'** Green LED, indicating that the preamplifier has transmitted control data to the main unit.

4.6.3 Handling

This section describes the handling of the preamplifier.



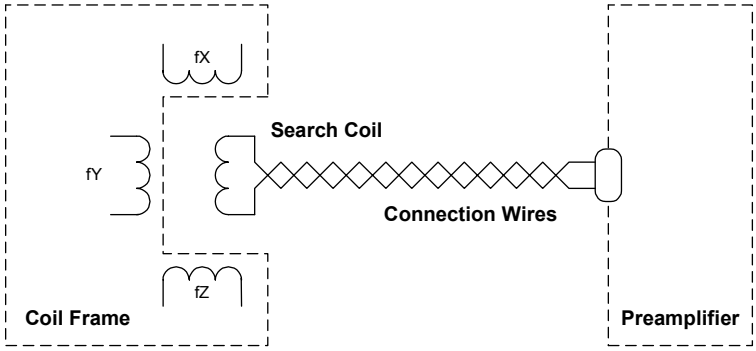
1	**Screw-on Flange** To achieve optimal shielding against irradiation of unwanted signals, the two connectors for the search coils on the front panel of the preamplifier are covered by the screw-on flange. To gain access to these connectors, remove the four mounting screws (2.) and lift off the flange. Remount the flange once the search coils are connected. Pay attention to the wire grommet (3.) and don't stuck the wires of the search coils between the flange and the base of the cabinet. Note: Irradiation of unwanted signals may cause an offset on the output data. Depending on your setup, you will not experience offset problems. Nevertheless it is suggested to use the flange in order to protect the search coil connectors against mechanical damage.
2	**Mounting Screws** Four mounting screws are used to fasten the flange. Use all four screws to optimize the shielding effectiveness of the flange.
3	**Wire Grommet** Carefully feed the wires of the search coils and use the grommet to avoid damage of the wires. An additional hose may be used to protect the wires.
4	**Mounting Holes** Two mounting holes (diameter 4.5 mm) are provided to fasten the preamplifier if required.

Notes:

- Irradiation from the coil frame to the preamplifier must be prevented. Preferably mount the preamplifier at least 1 m from the coil frame to minimize irradiation. To avoid problems see “6.0 System Optimization”.
- To achieve an optimal system performance, the level of the amplified search coil signal must be within a certain voltage range. This is achieved by setting the gain of the concerning channel of the preamplifier to a reasonable value, depending on the characteristics of the connected search coil and the magnitude of the magnetic field. See “5.4.5 Preamplifier Gain”, “5.3.10 Field Signals Magnitude” and “5.1 Display Area” for further details.

4.7 Search Coils

4.7.1 Functional Description



The magnetic field of the coil frame induces a voltage in the search coil. The spectral frequency components of the three field frequencies (fX, fY and fZ) of the induced voltage are proportional to the horizontal and vertical angular displacements of the search coil relative to the system's reference frame.

The search coils (for example 80 turns with a diameter of 2 mm) may be manufactured by the system administrator to fit the particular requirements. The CS681 is compatible with various search coils. To achieve optimal results, the characteristics of the used search coils must comply with the specification listed in the technical data of the CS681.

The diameter and the number of turns of a search coil determine the effective area:

$A_{eff} = n\ D^2\ pi / 4$

A_{eff} Effective area of the search coil
N Number of turns
D Diameter of one turn

A larger effective area of the search coil results in a higher induced voltage at a given magnetic flux density, therefore a large effective area is preferable with respect of the system’s signal to noise ratio.

The DC resistance of the search coil builds in conjunction with the input impedance of the preamplifier a voltage divider. Thus, in order to optimize the system’s signal to noise ratio and to minimize linearity errors, the DC resistance of the search coil should be as low as possible. Therefore, the search coil should consist of a material with a low specific resistance (e.g. copper or silver), the length of the wires should be as short as practicable and the cross section of the wires should be as large as practicable.

4.7.2 Connecting the Search Coils

Each search coil is connected to one channel of the preamplifier (see “4.6.2 Connectors and LED Indicators” for further details). The allocation of the channels preferably begins with channel 1, followed by channel 2 and so on (see “5.3.2 Channels Processing” for further details). In total, up to eight search coils may be connected concurrently.

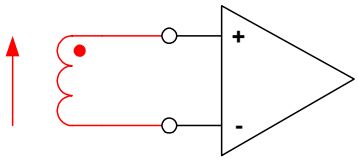
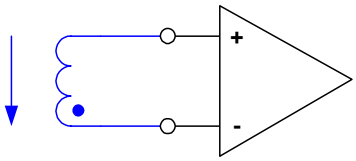
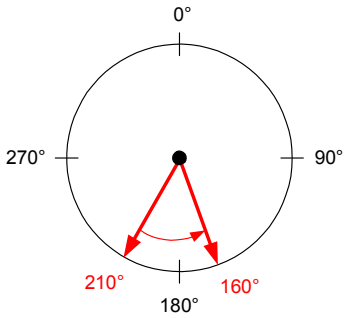
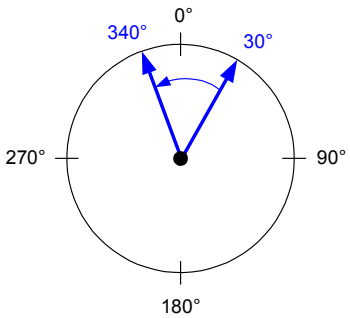
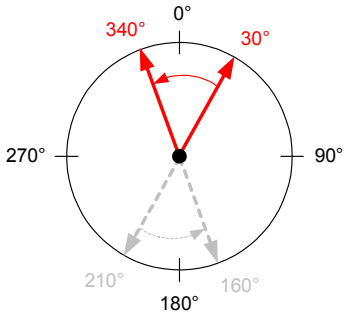
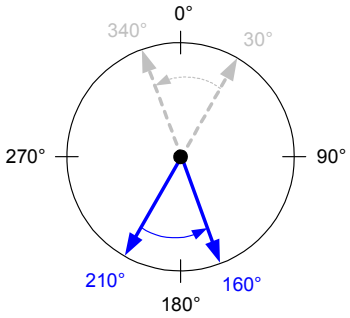
The connection wires of the search coil must be very tightly twisted together to prevent irradiation of unwanted signals. Use the delivered connectors (9 contacts pin connector MICRO-T) to connect the search coils directly to the preamplifier, i.e. avoid any additional interconnections between the search coils and the preamplifier to prevent irradiation of unwanted signals. The MICRO-T connectors require special care when soldering, i.e. avoid short circuits and overheating. Don’t forget to feed the wires trough the sleeve before soldering. The sleeve should be sealed with epoxy after soldering. See also “4.6.3 Handling” for further details.

4.7.3 Polarity

The table below depicts the correlation between the physical connection polarity of a given search coil and the resulting system output if the search coil is turned counter-clockwise by 50° in the horizontal plane.

The polarity of the system's output data of each channel can be reversed by the operator. This may be useful to reverse polarity without the need for changing the physical connection polarity of the respective search coil. See "5.4.4 Search Coil Polarity" for further details.

The polarity of each field signal may be reversed by the system administrator. A reversed field polarity results in reversed polarity in the respective axis of all search coils. See "5.3.12 Field Signal Phasing X2 / Y2 / Z" for further details.

Positive Connection Polarity	Negative Connection Polarity
 Search Coil connected to the Preamplifier with **positive connection polarity**	 Search Coil connected to the Preamplifier with **negative connection polarity**
 Output Data **'Standard Polarity'**	 Output Data **'Standard Polarity'**
 Output Data **'Reversed Polarity'**	 Output Data **'Reversed Polarity'**

4.7.4 Handling

This section describes the handling of the search coils.

The search coils should be operated at the 3D-centre of the coil frame (homogeneous area of the magnetic field, see “4.4.3 Handling” for further details). If this is not practicable, or if the homogeneity of the magnetic field is degraded for any other reason, the linearity of the system’s output data may become degraded. The characteristics of the used search coils may affect the frequency response linearity of the amplified search coil signal, which also may degrade the linearity of the system’s output data. The CS681 provides a gain correction for the respective X-, Y- and Z-vector length of each channel to correct nonlinearities. See “5.4.2 Gain Correction Mode” and “5.4.6 Gain Correction X / Y / Z” for further details.

As described above, the search coils must be wired such that the irradiation of unwanted offset signals is prevented. If this is not practicable, the resulting offset signal may lead to offset and / or noise on the system’s output data. The CS681 provides an offset correction for the respective X-, Y- and Z-vector length of each channel to cancel the effect of offset signals to the system’s output data. See “5.4.3 Offset Correction Mode” and “5.4.7 Offset Correction X / Y / Z” for further details.

To achieve an optimal system performance, the level of the amplified search coil signal must be within a certain voltage range (operational range). This is achieved by setting the gain of the concerning channel of the preamplifier to a reasonable value, depending on the characteristics of the connected search coil and the magnitude of the magnetic field. See “5.4.5 Preamplifier Gain”, “5.3.10 Field Signals Magnitude” and “5.1 Display Area” for further details.

Notes:

- In order to achieve optimal system performance, it is recommended to adjust the relevant channel settings after a search coil has been connected to the preamplifier. The CS681 provides several automatic tuning modes to support the operator, see “5.6 Automatic Tuning” for further details.
- An optimal quality of the search coil signals is essential to achieve high system performance. To avoid problems see “6.0 System Optimization”.

4.8 External Data Acquisition System

You may optionally use an external data acquisition system (e.g. an analog data acquisition board for a PC) to capture the analog output signals from the CS681. See also “5.7 Using the Analog Outputs” for further details.

The used data acquisition system should comply the minimum requirements listed below in order to ensure reliable results with the required precision.

Minimum requirements:

- Up to 24 analog input channels (see note 1)
- ± 5 Volt input voltage range (see note 2)
- Min. 10 MOhm / max. 100 pF input impedance
- Max. ± 100 nA input bias current
- Min. 16 kSamples / second conversion rate per input
- Min. 16 bits resolution

Note 1:

The format of the system’s analog outputs is selectable by the operator. Depending on the selected format, two or three parameters per channel are outputted. See “5.3.5 Analog Outputs Mode” for further details.

Note 2:

The voltage swing of the system’s analog outputs is selectable by the operator. This allows the optimal matching of the voltage range of the system’s analog outputs to the input voltage range of the used data acquisition system. See “5.3.4 Analog Outputs Swing” for further details.

4.9 External Computer

You may optionally connect an external computer to the USB interface of the CS681. See also “5.8 Using the USB Interface” for further details.

The used computer must comply the minimum requirements listed below. Note that the delivered software must be installed before the CS681 is connected for the first time to the computer. See “4.9.1 Software Installation“ for further details.

Minimum requirements:

- Pentium IV 2.4 GHz CPU or equivalent
- 256 MB of RAM
- 50 MB of available hard disk space
- CD-ROM or DVD-ROM drive
- 1024 x 768 or higher resolution video adapter and monitor
- USB 1.1 / 2.0 port
- Microsoft Windows 2000 Professional, Windows XP Professional or Windows XP Home
- In order to access online help (*.chm format), you must have installed Microsoft Internet Explorer 4.0 or higher

4.9.1 Software Installation

A CD-ROM with software and documentation is part of the delivery. The CD-ROM includes the following:

- An application software (CS681Tools.exe), which may be used to control the settings of the system and to visualize, analyze and capture the system’s output data over the USB. The software may also be used to upgrade the firmware of the system, see “7.0 Firmware Upgrade“ for further details.
- An ActiveX control (priCS681.ocx), which allows a user application software the straightforward communication with the system over the USB
- A dedicated DLL (CS681USB.dll) and a WDM driver (CS681USB.sys), which allow the ActiveX control the communication with the CS681 via the Windows USB driver stack and the USB physical layer
- The documentation for the ActiveX control (priCS681.chm)
- Examples for the use of the ActiveX control (LabVIEW VI and Visual Basic source code)
- The user manual of the CS681 (CS681 User Manual.pdf)

Following are the software installation guides for Windows 2000 and Windows XP.

Software Installation under Windows 2000

This section describes the software installation for the CS681 under Windows 2000.

Preliminary notes:

- The used computer should comply minimum requirements, see “4.9 External Computer”.
- You must have administrator privileges to install the software.
- The software must be installed before the CS681 is plugged for the first time into an USB port of the computer. Therefore, do not connect the USB interface of the CS681 before the software is installed. Continue with the instructions on the following pages to install the software.
- If you have already plugged the CS681 into an USB port of the computer and the "Found New Hardware Wizard" has popped up, click “Cancel” on that dialog, unplug the CS681 and continue with the instructions on the following pages to install the software.
- If you have already plugged the CS681 into an USB port of the computer and used the "Found New Hardware Wizard" to install a driver before the software was installed, you may have installed an incorrect driver. Perform “Step 4” of this section to check whether the correct driver has been installed. If not, uninstall the incorrect driver and continue with the instructions on the following pages to install the software.

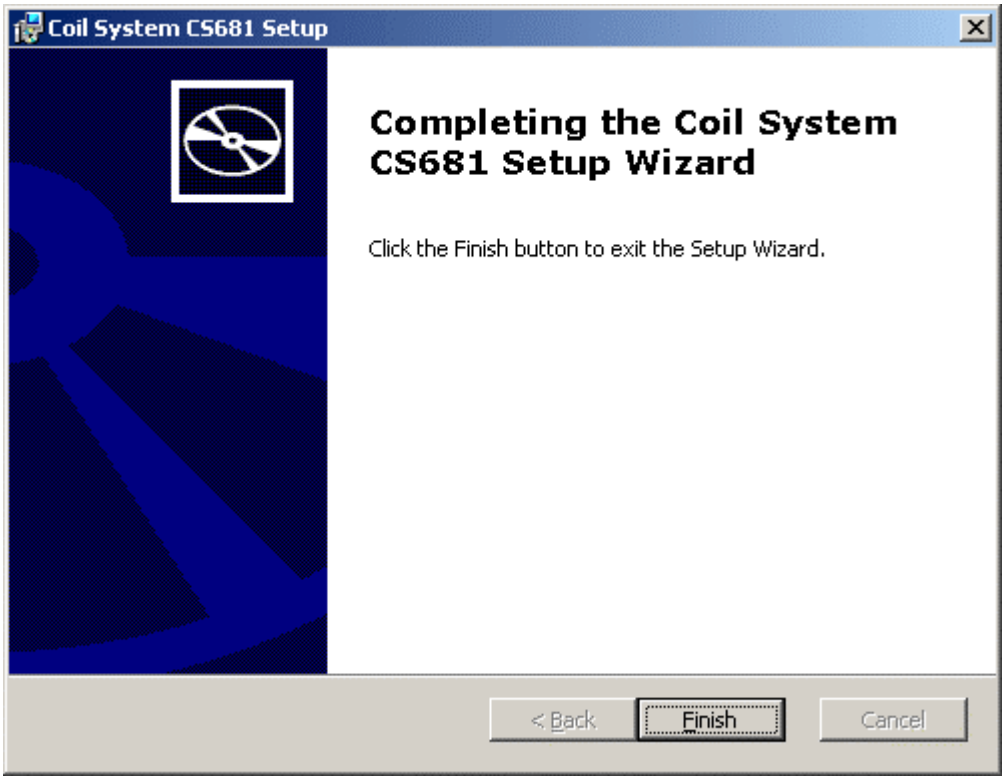
Step 1

Insert the delivered CD-ROM into an appropriate drive of the computer. The installation starts automatically if Autostart is enabled. Otherwise, run “setup.exe” from the top-level directory of the CD to start the installation:

Click “Next >” and follow the instructions of the “Setup Wizard” to install the software. During the software installation, the “Setup Wizard” will also pre-install the USB driver, which is required for the communication with the CS681.

Step 2

Finally, the “Setup Wizard” should display a message indicating that the software installation was successful:

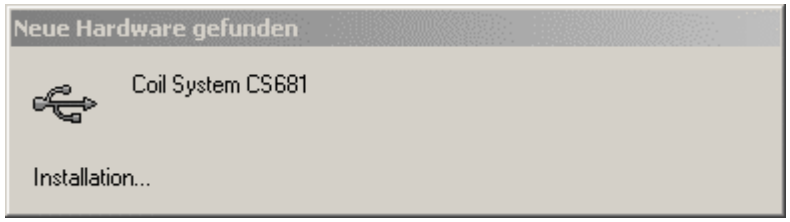


Click "Finish" to exit the “Setup Wizard”.

Step 3

After the software was successfully installed, plug the CS681 into an USB port of the computer and turn on the power of the CS681.

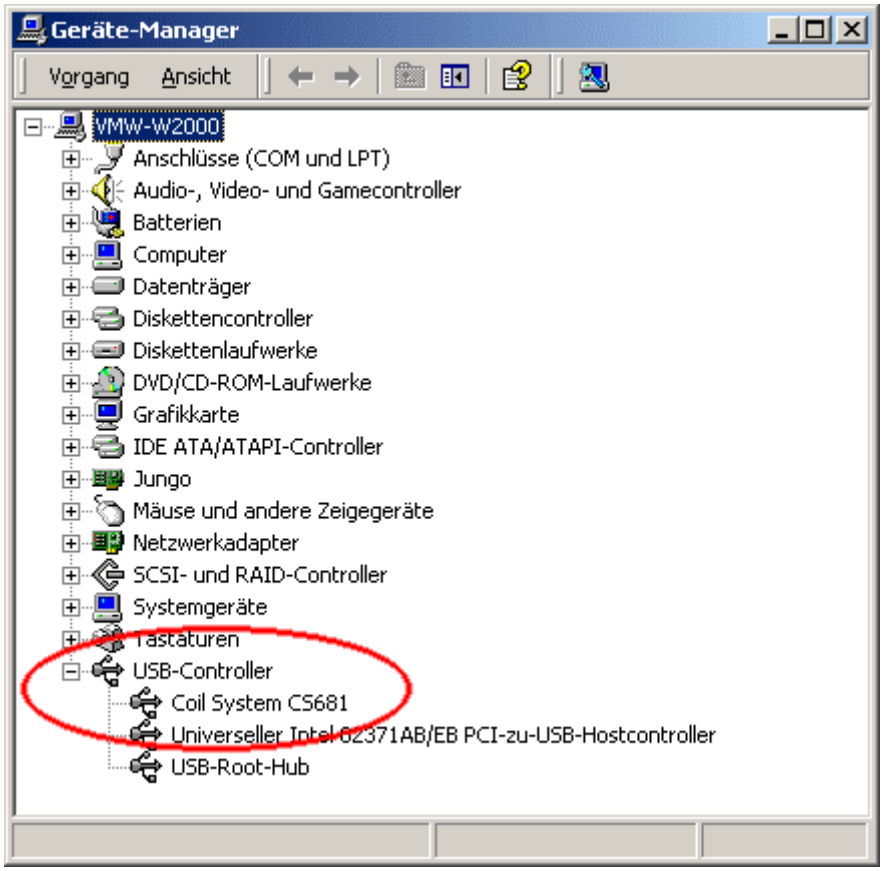
Windows 2000 will detect new hardware and automatically install the driver, which was pre-installed by the “Setup Wizard”:



Step 4

After Windows 2000 has installed the driver, check the successful installation.

Open the Device Manager (located in "Control Panel\System", then select the "Hardware" tab and click "Device Manger…"). The coil system CS681 should appear in the list of connected USB devices:



The computer is now ready to communicate with the CS681.

Software Installation under Windows XP

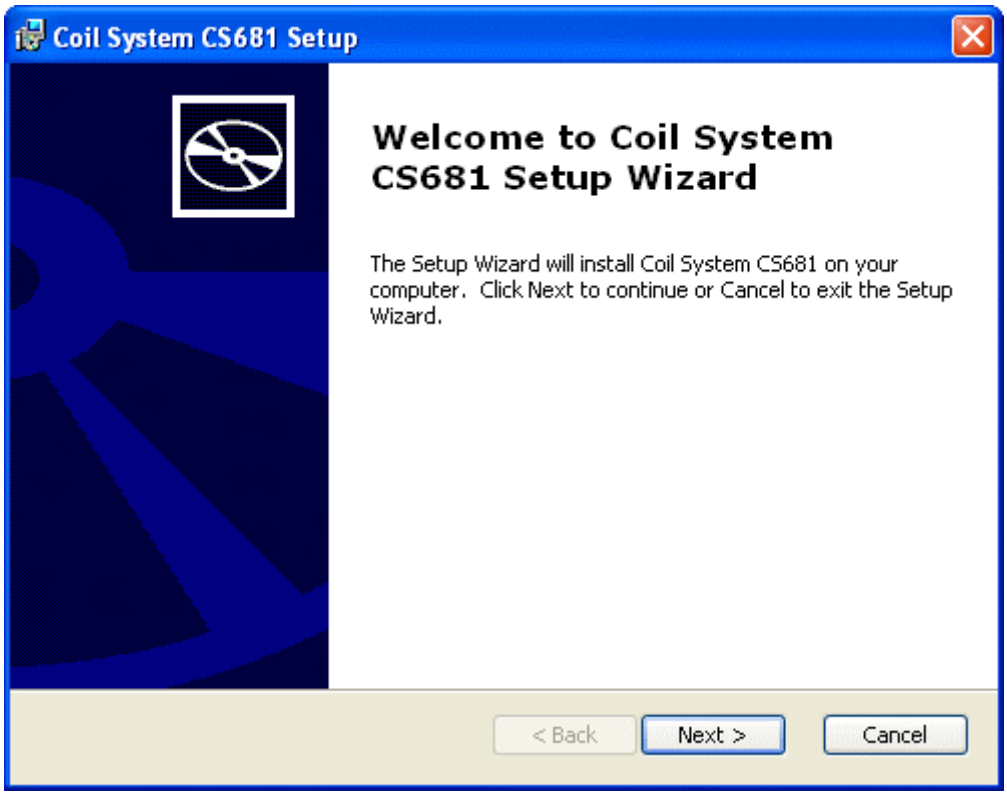
This section describes the software installation under Windows XP.

Preliminary notes:

- The used computer should comply minimum requirements, see “4.9 External Computer”.
- You must have administrator privileges to install the software.
- The software must be installed before the CS681 is plugged for the first time into an USB port of the computer. Therefore, do not connect the USB interface of the CS681 before the software is installed. Continue with the instructions on the following pages to install the software.
- If you have already plugged the CS681 into an USB port of the computer and the "Found New Hardware Wizard" has popped up, click “Cancel” on that dialog, unplug the CS681 and continue with the instructions on the following pages to install the software.
- If you have already plugged the CS681 into an USB port of the computer and used the "Found New Hardware Wizard" to install a driver before the software was installed, you may have installed an incorrect driver. Perform “Step 8” of this section to check whether the correct driver has been installed. If not, uninstall the incorrect driver and continue with the instructions on the following pages to install the software.

Step 1

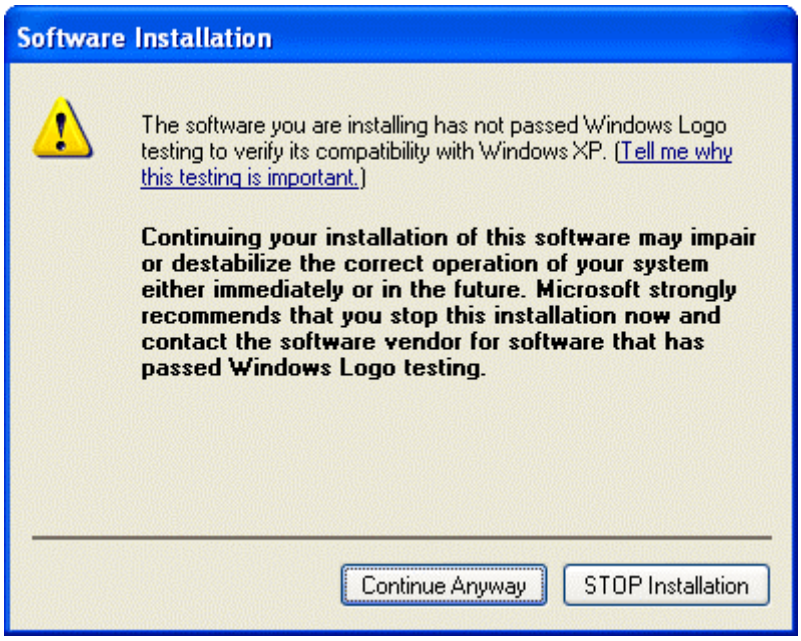
Insert the delivered CD-ROM into an appropriate drive of the computer. The installation starts automatically if Autostart is enabled. Otherwise, run “setup.exe” from the top-level directory of the CD to start the installation:



Click “Next >” and follow the instructions of the “Setup Wizard” to install the software.

Step 2

During the software installation, the “Setup Wizard” will also pre-install the USB driver, which is required for the communication with the CS681. The driver is not Microsoft WHQL certified, therefore the following window appears during the software installation:

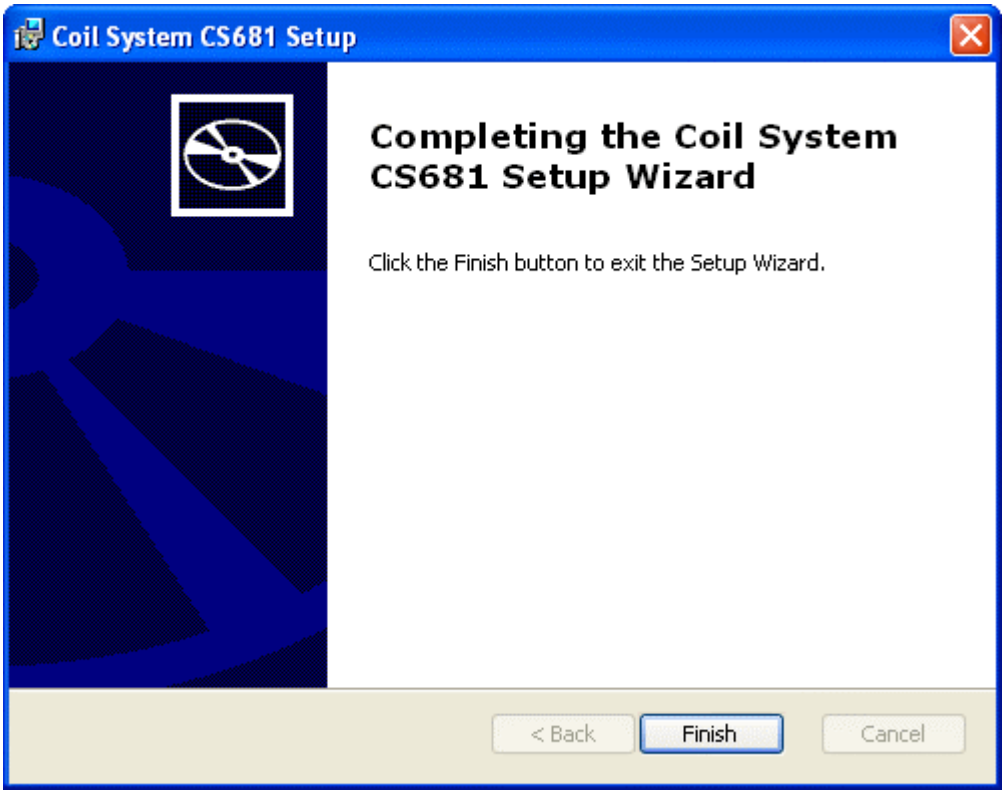


The message means that Primelec has not had Microsoft test the USB driver and certify it as Windows Logo compliant. However, the driver will **not** destabilize your system.

Click “Continue Anyway” to pre-install the driver.

Step 3

Finally, the “Setup Wizard” should display a message indicating that the software installation was successful:



Click "Finish" to exit the Setup Wizard.

Step 4

After the software was successfully installed, plug the CS681 into an USB port of the computer and turn on the power of the CS681.

Windows XP will detect new hardware and start the “Found New Hardware Wizard”.

Step 4a – Windows XP SP2 only

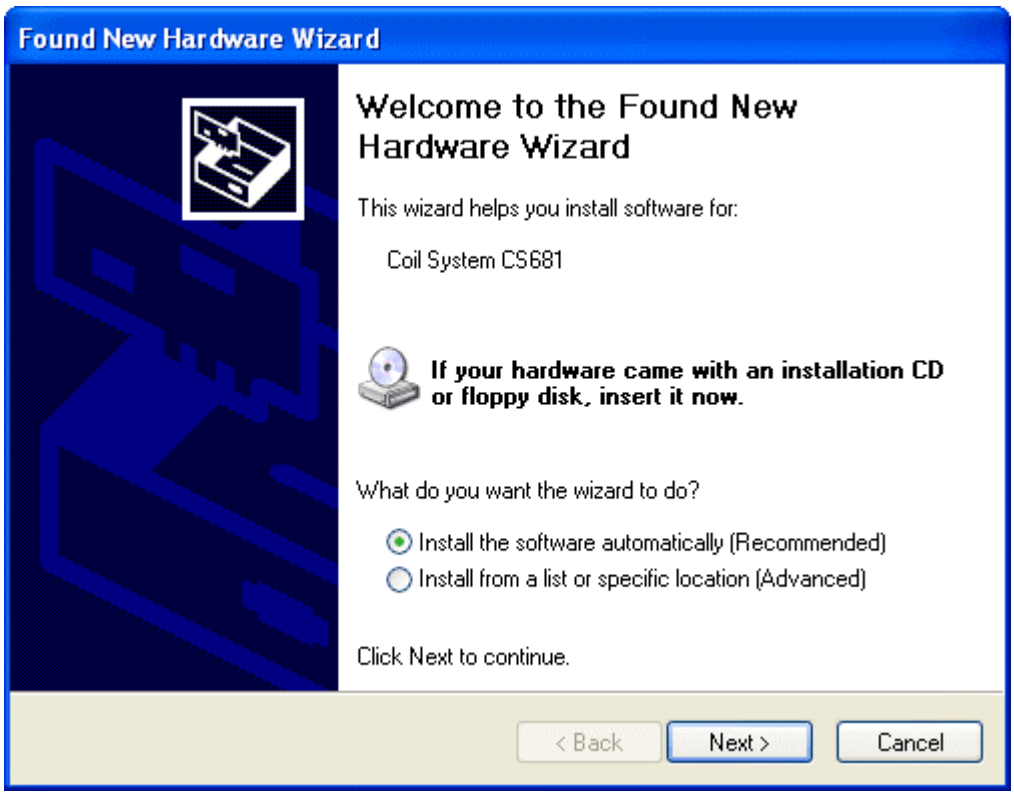
If you have Windows XP service pack 2, the first time a new USB device is plugged into a Windows XP system, this dialog box will appear indicating that the system has found a new hardware device and asking you whether or not to search for update software:

Choose “No, not this time” and click “Next >” to continue.

Step 5

The first time a new USB device is plugged in, a small dialog box will appear indicating that the system has found a new hardware device. There also may be a dialog box that informs the user that a device data base is being built or updated.

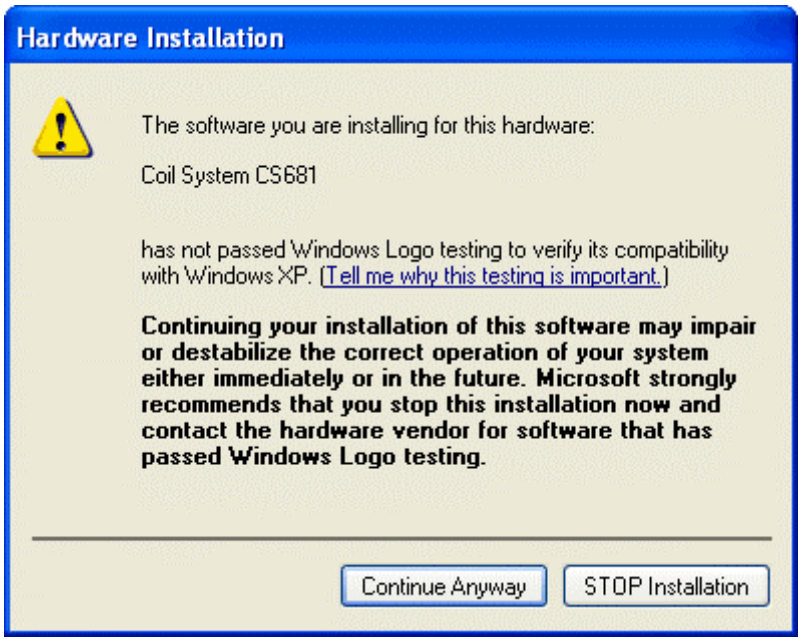
After these dialogs appear, the “Found New Hardware Wizard” dialog box is displayed:



Choose “Install the software automatically (Recommended)” and click “Next >” to continue.

Step 6

The “Found New Hardware Wizard” installs the driver, which was pre-installed by the “Setup Wizard”. The driver is not Microsoft WHQL certified, therefore the following window appears during the driver installation:

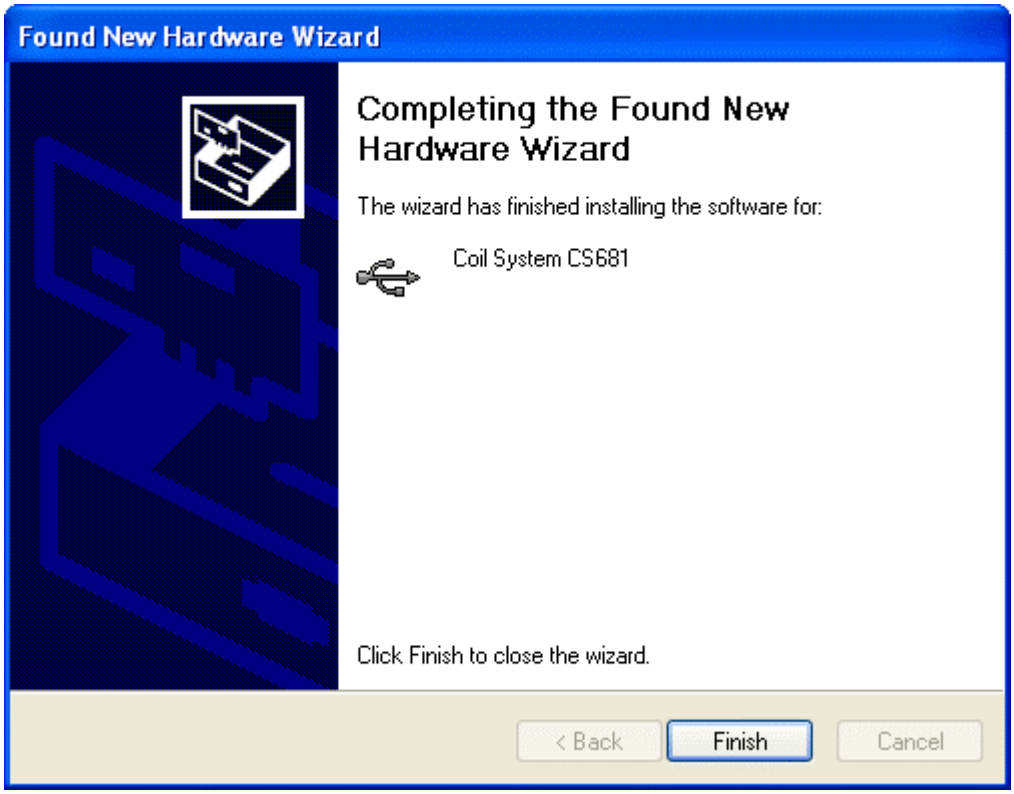


The message means that Primelec has not had Microsoft test the USB driver and certify it as Windows Logo compliant. However, the driver will **not** destabilize your system.

Click “Continue Anyway” to install the driver.

Step 7

Finally, the “Found New Hardware Wizard” should display a message indicating that the driver installation was successful:

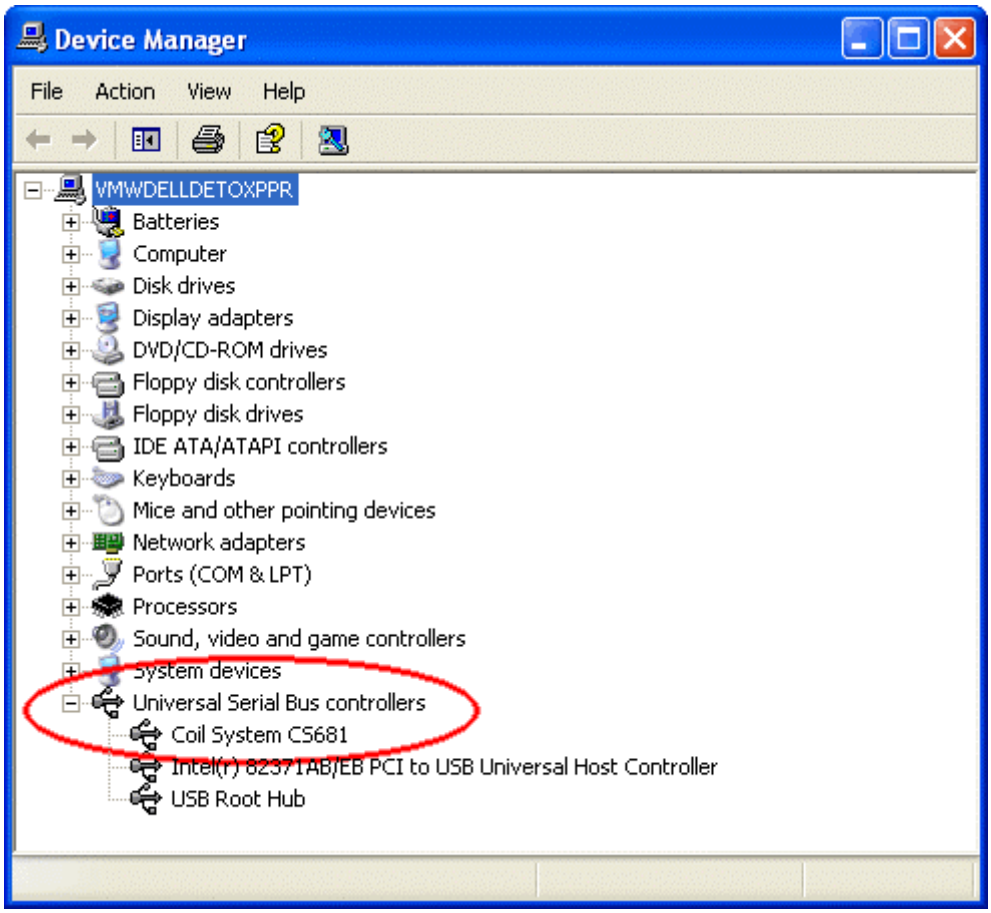


Click "Finish" to complete the driver installation.

Step 8

After Windows XP has installed the driver, check the successful installation.

Open the Device Manager (located in "Control Panel\System", then select the "Hardware" tab and click "Device Manger…"). The coil system CS681 should appear in the list of connected USB devices:

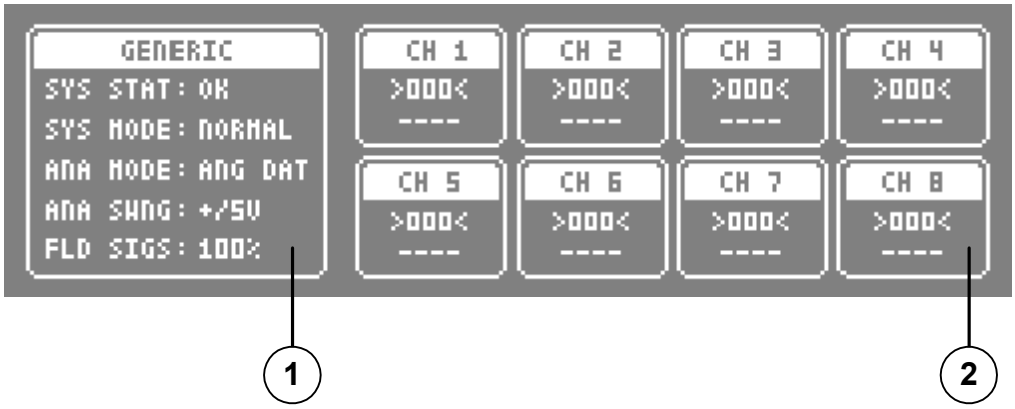


The computer is now ready to communicate with the CS681.

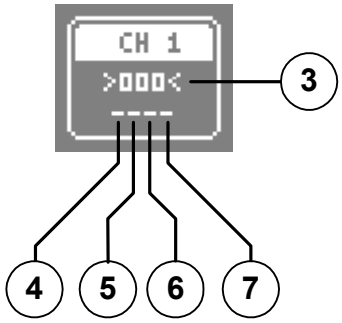
5.0 Operating Basics

5.1 Display Area

Whilst the menu system (see “5.2 Menu System”) is deactivated, the display is filled with many information and appears like this:



①	**Generic Settings (short form) and System Status** This section of the display indicates the actual settings of the most used generic settings. **SYS STAT:** System Status (OK or error number, see Appendix, “System Status”). **SYS MODE:** System Mode, see “5.3.1” for further details. **ANA MODE:** Analog Outputs Mode, see “5.3.5” for further details. **ANA SWNG:** Analog Outputs Swing, see “5.3.4” for further details. **FLD SIGS:** Field Signals Magnitude, see “5.3.10” for further details.
②	**Channel Settings (short form) and Level Indicator** These sections of the display indicate the actual settings of the most used channel settings of the channels 1 to 8. See the detailed description on the following pages.



③	**Channel Processing Indicator / Level Indicator** This line indicates whether the respective channel is processed and – if so – the actual level of the amplified search coil signal of the channel. The range of the level indicator is from 0 to 100. **IDLE** indicates that the concerning channel is not processed (see "5.3.2 Channels Processing" for further details. To achieve an optimal system performance, the level of the amplified search coil signal of a processed channel with a connected search coil must always be within a certain voltage range (operational range). This is achieved by setting the gain of the preamplifier to a reasonable value, depending on the characteristics of the connected search coil and the magnitude of the magnetic field. See "5.4.5 Preamplifier Gain" and "5.3.10 Field Signals Magnitude" for further details. **Indicated Level is below 32:** The level of the amplified search coil signal is too low, therefore the signal to noise ratio of this channel's output data may be degraded. Increase the gain of the preamplifier for this channel and / or increase the magnitude of the magnetic field until the indicated level is in the range from 32 to 93. Note: Too low levels are marked by brackets, e.g. >012<. **Indicated Level is in the range from 32 to 93:** If a channel is processed, the indicated level should always be in the range from 32 to 93, independently of the position and angular orientation of the connected search coil. This ensures a good signal to noise ratio of the channel's output data and prevents overdriving of the system's ADC due to the amplified search coil signal is within the operational range. **Indicated Level is above 93:** The level of the amplified search coil signal is too high, therefore the system's ADC may be overdriven and the output data of this channel may be incorrect. It is essential to decrease the gain of the preamplifier for this channel and / or decrease the magnitude of the magnetic field until the indicated level is in the range from 32 to 93. Note: Too high levels are marked by brackets, e.g. <100>.

④	**Low Pass Filter** This character indicates the actual setting of the low pass filter of the respective channel, see “5.4.1 Low Pass Filter” for further details. **–** The low pass filter is disabled (bypassed) **1** The low pass filter is active, characteristics ‘Bessel 500 Hz’ **2** The low pass filter is active, characteristics ‘Bessel 200 Hz’ **3** The low pass filter is active, characteristics ‘Bessel 50 Hz’ **4** The low pass filter is active, characteristics ‘Butterworth 500 Hz’ **5** The low pass filter is active, characteristics ‘Butterworth 200 Hz’ **6** The low pass filter is active, characteristics ‘Butterworth 50 Hz’ **7** The low pass filter is active, characteristics ‘Moving Average 8’ **8** The low pass filter is active, characteristics ‘Moving Average 16’ **9** The low pass filter is active, characteristics ‘Moving Average 32’
⑤	**Gain Correction Mode** This character indicates the actual setting of the gain correction mode of the respective channel, see “5.4.2 Gain Correction Mode” for further details. **–** The gain correction is disabled (not in use) **G** The gain correction is enabled
⑥	**Offset Correction Mode** This character indicates the actual setting of the offset correction mode of the respective channel, see “5.4.3 Offset Correction Mode” for further details. **–** The offset correction is disabled (not in use) **O** The offset correction is enabled
⑦	**Search Coil Polarity** This character indicates the actual setting of the polarity of the search coil of the respective channel, see “5.4.4 Search Coil Polarity” for further details. **–** Standard polarity **P** Reversed polarity

The following examples depict some display sections and explain the respective settings.

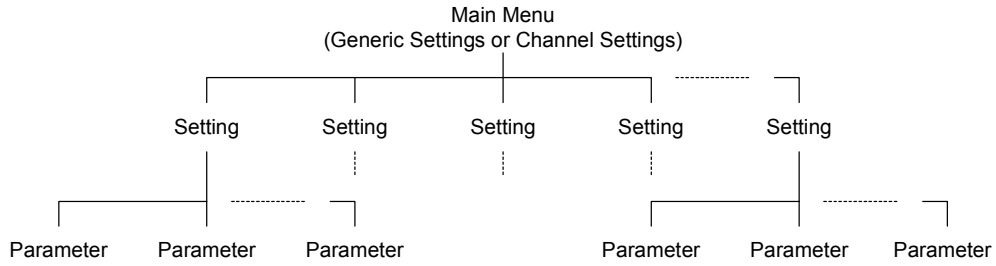
Display	Actual settings of the concerning channel (short form)
	Channel 2: • The channel is processed, the level of the amplified search coil signal is too low • The low pass filter is disabled (bypassed) • The gain correction is enabled • The offset correction is disabled • The search coil polarity is standard
	Channel 3: • The channel is processed, the level of the amplified search coil signal is within the operational range • The low pass filter is active (‘Bessel 50 Hz’) • The gain correction is disabled • The offset correction is enabled • The search coil polarity is reversed
	Channel 4: • The channel is processed, the level of the amplified search coil signal is too high • The low pass filter is disabled (bypassed) • The gain correction is disabled • The offset correction is disabled • The search coil polarity is standard
	Channel 5: • The channel is not processed • The low pass filter is active (‘Bessel 200 Hz’) • The gain correction is enabled • The offset correction is enabled • The search coil polarity is reversed

5.2 Menu System

This chapter describes the use of the menu system of the CS681.

The menu system allows a user friendly, menu controlled operation of the CS681 by using the touch screen of the display, which responds to the pressure of a finger or a fingernail. Exercise care in using the touch screen. It is designed for finger-pressure only. Do not touch with pen, pencil, or any sharp object! Use a damp, soft and lint-free cloth to clean the display. Never use any cleansing agents or solvents!

The menu system provides two main menus, one to control the generic settings and one to control the channel settings of the eight channels. Both main menus are split into a top-down tree structure with two levels:



Note:

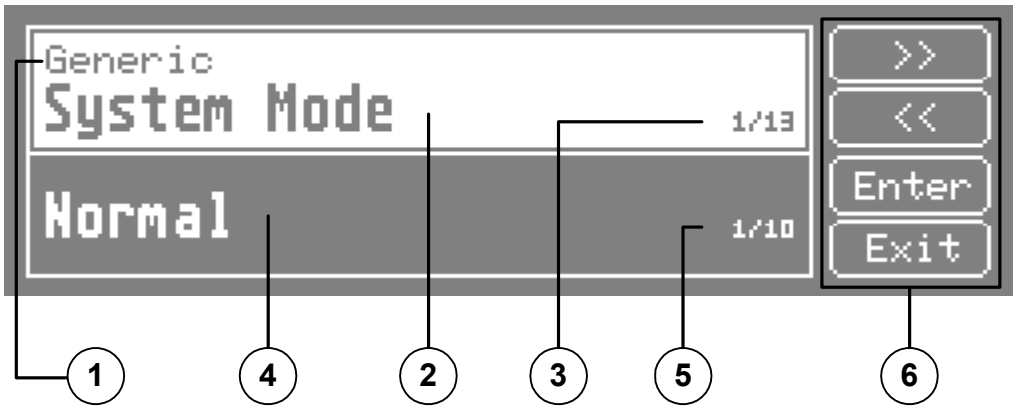
Not all settings of the CS681 are accessible by the menu system. For further details see “5.3 Generic Settings“ and “5.4 Channel Settings“.

5.2.1 Using the Menu System – Generic Settings

This section describes the use of the menu system to control the generic settings. See also “5.3 Generic Settings” for a detailed description of all generic settings.

Touching the framed section in this area of the display will activate the menu system in order to control the generic settings:

Once the menu system is activated, the display appears like this:



①	**Indicator of active menu system** Indicates that the menu system to control the generic settings is active.
②	**Settings** The settings are displayed in the upper section of the display. Note: The figure above depicts the settings selected (highlighted).
③	**Indicator of selected setting / number of settings**
④	**Parameters** The parameters of the setting are displayed in the lower section of the display.
⑤	**Indicator of selected parameter / number of parameters**

⑥	**Keys ⋘ and ⋙** If the settings are currently selected, use these keys to scroll through the settings. If the parameters are currently selected, use these keys to scroll through the parameters of the setting. **Key** Enter If the settings are currently selected, use this key to switch to the parameter selection of the setting, i.e. the parameters will be selected. If the parameters are currently selected, use this key to accept and save the selected parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again. **Key** Exit If the settings are currently selected, use this key to exit the menu system. If the parameters are currently selected, use this key to discard the selected parameter of the setting, i.e. to recall the previously saved parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again.

Note:

After the menu system has been activated, the previously selected generic setting is displayed.

Example

To disable the audible key click of the touch screen, follow the steps listed below.

The setting for the audible key click is a generic setting. Therefore, activate the menu system in order to control the generic settings by touching the framed section of the display:

The menu system is activated. Note that the previously selected generic setting is displayed, in this example ‘System Mode’:

Press the keys ⋘ or ⋙ to scroll through the settings until the setting ‘Audible Key Click’ is displayed. Note the indicator of the selected setting / number of settings: The setting ‘Audible Key Click’ is the 9. setting of total 13 settings:

Press the key Enter to switch to the parameter selection of the setting, i.e. the parameters will be selected:

Press the keys ⩽ or ⩾ to scroll through the parameters of the setting until the parameter 'Disabled' is displayed. Note the indicator of the selected parameter / number of parameters: The parameter 'Disabled' is the 1. parameter of total 2 parameters for this setting:

Press the key Enter to accept and save the selected parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again:

Press the key Exit to exit the menu system:

The menu system is deactivated. Look at the section of the display which indicates the current settings of the most used generic settings. No changing is apparent due to the setting of ‘Audible Key Click’ is not indicated in this section.

5.2.2 Menu System Reference – Generic Settings

This section lists all entries of the menu system concerning generic settings. The respective default parameter of the setting is printed in bold characters.

Note:

For a detailed description of all generic settings see “5.3 Generic Settings”.

Generic Setting		Parameters	
System Mode	1 / 13	**Normal**	**1 / 10**
		Test 1 (Min)	2 / 10
		Test 2 (Mid)	3 / 10
		Test 3 (Max)	4 / 10
		Test 4 (Rect # 1)	5 / 10
		Test 5 (Rect # 2)	6 / 10
		Test 6 (Rect # 3)	7 / 10
		Test 7 (Ramp # 1)	8 / 10
		Test 8 (Ramp # 2)	9 / 10
		Test 9 (Ramp # 3)	10 / 10
Channels Processing	2 / 13	CH 1 to CH 2	1 / 3
		CH 1 to CH 4	2 / 3
		CH 1 to CH 8	**3 / 3**
Power On Mode	3 / 13	**Default**	**1 / 2**
		Last State	2 / 2
Analog Outputs Swing	4 / 13	Disabled	1 / 6
		+/- 2 Volt	2 / 6
		+/- 2.5 Volt	3 / 6
		+/- 4 Volt	4 / 6
		+/- 4.5 Volt	5 / 6
		+/- 5 Volt	**6 / 6**

Generic Setting		Parameters	
Analog Outputs Mode	5 / 13	**Angular Data**	**1 / 4**
		Vector Length Fixed	2 / 4
		Vector Length Fitted	3 / 4
		Vector Angle	4 / 4
Display Contrast	6 / 13	10 %	1 / 10
		20 %	2 / 10
		30 %	3 / 10
		40 %	4 / 10
		50 %	5 / 10
		60 %	**6 / 10**
		70 %	7 / 10
		80 %	8 / 10
		90 %	9 / 10
		100 %	10 / 10
Display Brightness	7 / 13	Off	1 / 4
		Dark	2 / 4
		Medium	**3 / 4**
		Brigth	4 / 4
Touch Screen Mode	8 / 13	Disabled	1 / 2
		Enabled	**2 / 2**
Audible Key Click	9 / 13	Disabled	1 / 2
		Enabled	**2 / 2**

Generic Setting		Parameters	
Field Signals Magnitude	10 / 13	Off	1 / 11
		10 %	2 / 11
		20 %	3 / 11
		30 %	4 / 11
		40 %	5 / 11
		50 %	6 / 11
		60 %	7 / 11
		70 %	8 / 11
		80 %	9 / 11
		90 %	10 / 11
		100 %	**11 / 11**
Save Setup (see note 1)	11 / 13	User Memory 1	1 / 10
		User Memory 2	2 / 10
		User Memory 3	3 / 10
		User Memory 4	4 / 10
		User Memory 5	5 / 10
		User Memory 6	6 / 10
		User Memory 7	7 / 10
		User Memory 8	8 / 10
		User Memory 9	9 / 10
		User Memory 10	10 / 10

Generic Setting		Parameters	
Recall Setup (see note 1)	12 / 13	User Memory 1	1 / 11
		User Memory 2	2 / 11
		User Memory 3	3 / 11
		User Memory 4	4 / 11
		User Memory 5	5 / 11
		User Memory 6	6 / 11
		User Memory 7	7 / 11
		User Memory 8	8 / 11
		User Memory 9	9 / 11
		User Memory 10	10 / 11
		Factory Settings	11 / 11
Automatic Tuning (see note 2)	13 / 13	Preamplifier Gain	1 / 4
		Gain Correction XYZ	2 / 4
		Offset Correction XYZ	3 / 4
		Phase Correction XYZ	4 / 4

Note 1:

The menu entries ‘Save Setup’ and ‘Recall Setup’ are not used to control a particular generic setting. Instead, they are used to save and recall all settings, see “5.5 Save and Recall Setup” for further details.

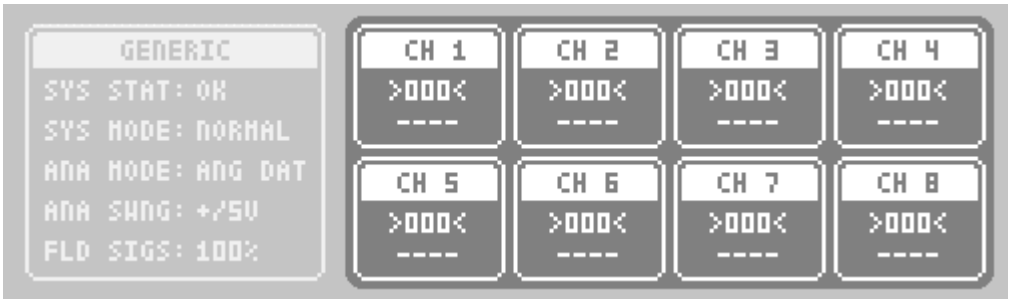
Note 2:

The menu entry ‘Automatic Tuning’ is not used to control a particular generic setting. Instead, it is used to start automatic tuning of all channels, see “5.6 Automatic Tuning” for further details.

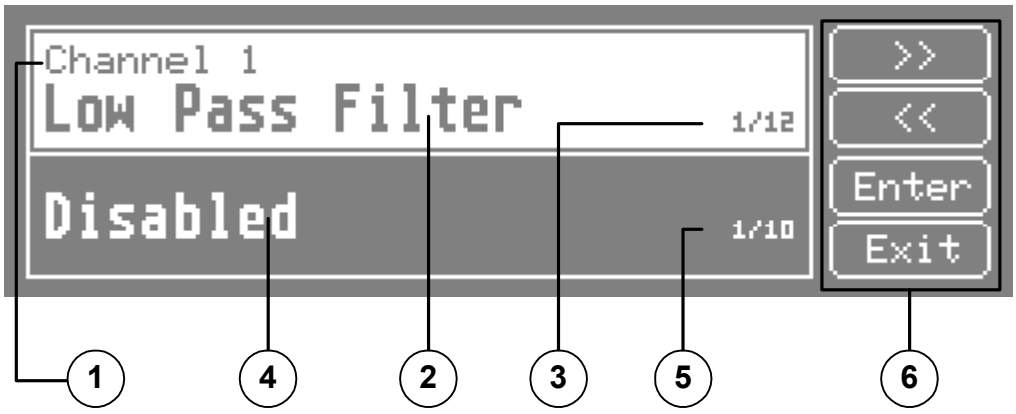
5.2.3 Using the Menu System – Channel Settings

This section describes the use of the menu system to control the channel settings. See also “5.4 Channel Settings“ for a detailed description of all channel settings.

Touching a framed section in this area of the display will activate the menu system in order to control the respective channel settings:



Once the menu system is activated, the display appears like this:



①	**Indicator of active menu system** Indicates that the menu system to control the settings of the indicated channel is active.
②	**Settings** The settings are displayed in the upper section of the display. Note: The figure above depicts the settings selected (highlighted).
③	**Indicator of selected setting / number of settings**
④	**Parameters**(see also information concerning numeric parameters) The parameters of the setting are displayed in the lower section of the display.

⑤	**Indicator of selected parameter / number of parameters** (see also next page concerning numeric parameters)
⑥	**Keys ≪ and ≫** If the settings are currently selected, use these keys to scroll through the settings. If the parameters are currently selected, use these keys to scroll through the parameters of the setting (see also next page concerning numeric parameters). **Key** Enter If the settings are currently selected, use this key to switch to the parameter selection of the setting, i.e. the parameters will be selected. If the parameters are currently selected, use this key to accept and save the selected parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again. **Key** Exit If the settings are currently selected, use this key to exit the menu system. If the parameters are currently selected, use this key to discard the selected parameter of the setting, i.e. to recall the previously saved parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again.

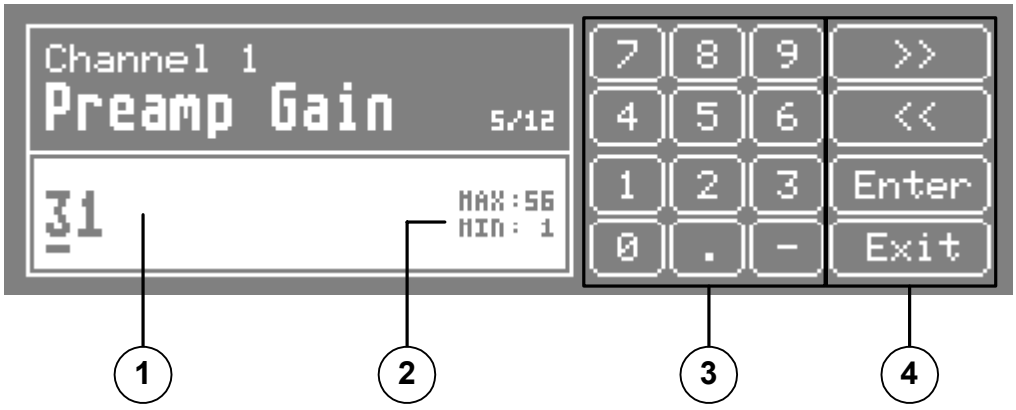
Note:

After the menu system has been activated, the previously selected channel setting is displayed.

Numeric Parameters

The parameter of certain settings is not selected by scrolling trough the parameters. Instead, the concerned settings (namely ‘Preamplifier Gain’, ‘Gain Correction X / Y / Z’ and ‘Offset Correction X / Y / Z’) use numeric parameters, which are entered by the use of the numeric keys.

For example, the figure below depicts the appearance of the display used to enter the numeric parameter of the preamplifier gain:



①	**Numeric Parameter**
②	**Indicator of Valid Range** Indicates the valid of range of the numeric parameter of the setting.
③	**Numeric Keys** Use these keys to enter the numeric parameter of the setting. Note: Depending on the setting, the keys . and / or - are not accepted.
④	**Keys << and >>** Use these keys to change the cursor position within the numeric parameter if required. **Key** Enter Use this key to accept and save the entered numeric parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again (see previous page). **Key** Exit Use this key to discard the entered numeric parameter of the setting, i.e. to recall the previously saved numeric parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again (see previous page).

Example

To set the gain of channel 6 of the preamplifier to 41, follow the steps listed below.

Note the section of the display with the line which indicates the actual level of the amplified search coil signal of channel 6 in the figure below. >022< indicates that the level is too low, therefore the signal to noise ratio of this channel's output data may be degraded. We will now increase manually the gain of the preamplifier for this channel to increase the level of the amplified search coil signal.

The setting for the gain of the preamplifier is a channel setting. Therefore, activate the menu system in order to control the settings of channel 6 by touching the framed section of the display:

The menu system is activated. Note that the previously selected channel setting is displayed, in this example 'Low Pass Filter':

Press the keys ≪ or ≫ to scroll through the settings until the setting ‘Preamplifier Gain’ is displayed. Note the indicator of the selected setting / number of settings: The setting ‘Preamplifier Gain’ is the 5. setting of total 12 settings:

Press the key Enter to switch to the parameter selection of the setting, i.e. the parameters will be selected:

Use the numeric keys to enter the numeric parameter of the setting, i.e. enter '41'. If required, use the keys ⋘ and ⋙ to change the cursor position within the numeric parameter. Note the indicator of the valid range: The valid range of the setting 'Preamp Gain' is from 1 to 56:

Press the key Enter to accept and save the entered numeric parameter of the setting. The menu system switches back to the setting selection, i.e. the settings will be selected again:

Press the key Exit to exit the menu system:

The menu system is deactivated. Note the section of the display with the line which indicates the actual level of the amplified search coil signal of channel 6 in the figure above. The indicated level is now higher and within the operational range.

5.2.4 Menu System Reference – Channel Settings

This section lists all entries of the menu system concerning channel settings. The respective default parameter of the setting is printed in bold characters.

Note:

For a detailed description of all channel settings see “5.4 Channel Settings”.

Channel Setting		Parameters	
Low Pass Filter	1 / 12	**Disabled**	**1 / 10**
		Bessel 500 Hz	2 / 10
		Bessel 200 Hz	3 / 10
		Bessel 50 Hz	4 / 10
		Butterworth 500 Hz	5 / 10
		Butterworth 200 Hz	6 / 10
		Butterworth 50 Hz	7 / 10
		Moving Average 8	8 / 10
		Moving Average 16	9 / 10
		Moving Average 32	10 / 10
Gain Correction	2 / 12	**Disabled**	**1 / 2**
		Enabled	2 / 2
Offset Correction	3 / 12	**Disabled**	**1 / 2**
		Enabled	2 / 2
Search Coil Polarity	4 / 12	**Standard**	**1 / 2**
		Reversed	2 / 2
Preamplifier Gain	5 / 12	Numeric Parameter	**31**
		Valid Range:	1 to 56
Gain Correction X	6 / 12	Numeric Parameter	**1.0000**
		Valid Range:	0.0000 to 20.0000
Gain Correction Y	7 / 12	Numeric Parameter	**1.0000**
		Valid Range:	0.0000 to 20.0000

Channel Setting		Parameters
Gain Correction Z	8 / 12	Numeric Parameter **1.0000** Valid Range: 0.0000 to 20.0000
Offset Correction X	9 / 12	Numeric Parameter **0** Valid Range: -250000 to 250000
Offset Correction Y	10 / 12	Numeric Parameter **0** Valid Range: -250000 to 250000
Offset Correction Z	11 / 12	Numeric Parameter **0** Valid Range: -250000 to 250000
Automatic Tuning (see note)	12 / 12	Preamplifier Gain 1 / 4 Gain Correction XYZ 2 / 4 Offset Correction XYZ 3 / 4 Phase Correction XYZ 4 / 4

Note:

The menu entry ‘Automatic Tuning’ is not used to control a particular channel setting. Instead, it is used to start automatic tuning of the respective channel, see “5.6 Automatic Tuning” for further details.

5.3 Generic Settings

This chapter describes all generic settings of the CS681.

We distinguish two types of generic settings: The critical generic settings and the non-critical generic settings.

Critical generic settings concern those settings which have been adjusted specifically to your system at the factory. Therefore, the menu system of the CS681 don't supports the changing of critical settings and the operator may not change the critical settings in order to prevent accidental adjusting. If required, the system administrator may change the critical settings over the USB interface by using the delivered application software. See "5.8 Using the USB Interface" for further details.

Non-critical generic settings concern those settings which don't require system specific adjustment. Therefore, non-critical settings may be changed by the operator or the system administrator by using either the menu system or the application software.

Note:

Immediately after a generic setting changed, the system's output data will not be updated during a short period of time (120 ms typical).

Following is a detailed description of all generic settings. The respective default parameter of each setting is printed in bold characters.

5.3.1 System Mode

Function: Determines the basic modes of the CS681

Setting Type: Non-Critical

Menu System: Supported, generic setting 1 / 13

Parameters: 10 parameters selectable

Parameter	Description
Normal	Measuring mode. The CS681 outputs the measuring data of the processed channels on the analog outputs and the USB interface. Note: This mode is always selected after system power is turned on, independently of the setting of 'Power On Mode'.
Test 1 (Min)	Test mode 1. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 2 (Mid)	Test mode 2. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 3 (Max)	Test mode 3. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 4 (Rect #1)	Test mode 4. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 5 (Rect #2)	Test mode 5. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 6 (Rect #3)	Test mode 6. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 7 (Ramp #1)	Test mode 7. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 8 (Ramp #2)	Test mode 8. The CS681 outputs a test signal on the analog outputs and the USB interface.
Test 9 (Ramp #3)	Test mode 9. The CS681 outputs a test signal on the analog outputs and the USB interface.

Note: For a detailed description of the test signals see Appendix, "Test Modes".

5.3.2 Channels Processing

Function: Determines the number of processed channels

Setting Type: Non-Critical

Menu System: Supported, generic setting 2 / 13

Parameters: 3 parameters selectable

Parameter	Description
CH 1 to CH 2	Only channel 1 and channel 2 are processed, i.e. no output data is present for the non-processed channels 3 to 8. The output data rate of the processed channels is 8 kHz (i.e. 125 us refresh rate of the output data on the analog outputs and the USB interface). Preferably use this parameter to achieve the highest output data rate if your application consists of up to two search coils.
CH 1 to CH 4	Only channel 1, channel 2, channel 3 and channel 4 are processed, i.e. no output data is present for the non-processed channels 5 to 8. The output data rate of the processed channels is 4 kHz (i.e. 250 us refresh rate of the output data on the analog outputs and the USB interface). Preferably use this parameter to achieve the highest output data rate if your application consists of three or four search coils.
CH 1 to CH 8	All eight channels are processed. The output data rate of the processed channels is 2 kHz (i.e. 500 us refresh rate of the output data on the analog outputs and the USB interface). Use this parameter if your application consists of more than four search coils. Otherwise you may use an other setting in order to benefit from the higher output data rate achieved by the other settings (see above).

5.3.3 Power On Mode

Function: Determines the behavior of the CS681 after system power is turned on

Setting Type: Non-Critical

Menu System: Supported, generic setting 3 / 13

Parameters: 2 parameters selectable

Parameter	Description
Default	When turning the CS681 on, all settings (i.e. the generic settings and the channel settings of all eight channels) are initialized to default factory settings.
Last State	When turning the CS681 on, all settings (i.e. the generic settings and the channel settings of all eight channels) return to the settings that were in place when the system power was turned off. Note 1: The following settings are always initialized to default factory settings when turning the CS681 on, even if 'Last State' is selected: - System Mode (Normal) - Touch Screen Mode (Enabled) Note 2: The setting of 'Display Brightness' to 'Off' will never be recalled after system power is turned on, even if 'Last State' is selected. Instead, if this parameter was selected when the system power was turned off, medium backlighting of the display is selected after system power is turned on.

5.3.4 Analog Outputs Swing

Function: Determines the peak-to-peak voltage swing of the analog outputs. This is useful to match the voltage range of the analog outputs to the input voltage range of the optionally used data acquisition system.

Setting Type: Non-Critical

Menu System: Supported, generic setting 4 / 13

Parameters: 6 parameters selectable

Parameter	Description
Disabled	The analog outputs are not updated, 0 V is outputted on all analog outputs.
+/- 2 Volt	The peak-to-peak voltage swing of the analog outputs is +/- 2 V.
+/- 2.5 Volt	The peak-to-peak voltage swing of the analog outputs is +/- 2.5 V.
+/- 4 Volt	The peak-to-peak voltage swing of the analog outputs is +/- 4 V.
+/- 4.5 Volt	The peak-to-peak voltage swing of the analog outputs is +/- 4.5 V.
+/- 5 Volt	The peak-to-peak voltage swing of the analog outputs is +/- 5 V.

5.3.5 Analog Outputs Mode

Function: Determines the format of the output data for the analog outputs

Setting Type: Non-Critical

Menu System: Supported, generic setting 5 / 13

Parameters: 4 parameters selectable

<table>
<tr><th>Parameter</th><th>Description</th></tr>
<tr><td>Angular Data</td><td>The angular orientations in the horizontal plane (α) and the vertical plane (β) are outputted.</td></tr>
<tr><td>Vector Length Fixed</td><td>The vector lengths X, Y and Z (X-, Y- and Z-axis) are outputted. The scaling range is fixed, from -250’000 to 250’000.</td></tr>
<tr><td>Vector Length Fitted</td><td>The vector lengths X, Y and Z (X-, Y- and Z-axis) are outputted. The scaling range is dynamically fitted after each acquisition of data such that the largest absolute value of the vector lengths determines the scaling range, i.e.
<pre>vect_len_fit = abs(vect_len_x);
if ((abs(vect_len_y) > vect_len_fit)
        vect_len_fit = abs(vect_len_y);
if ((abs(vect_len_z) > vect_len_fit)
        vect_len_fit = abs(vect_len_z);
scale_max = vect_len_fit;
scale_min = -1 * vect_len_fit;</pre>
Example 1 (Analog Outputs Swing = +/- 5 V):
<table>
<tr><th></th><th>X</th><th>Y</th><th>Z</th></tr>
<tr><td>Vect Len</td><td>-100000</td><td>25000</td><td>-10000</td></tr>
<tr><td>V Out (V)</td><td>-5.000</td><td>1.250</td><td>-0.500</td></tr>
</table>
Example 2 (Analog Outputs Swing = +/- 5 V):
<table>
<tr><th></th><th>X</th><th>Y</th><th>Z</th></tr>
<tr><td>Vect Len</td><td>20000</td><td>-8000</td><td>80000</td></tr>
<tr><td>V Out (V)</td><td>1.25</td><td>-0.500</td><td>5.000</td></tr>
</table>
Note:
Using this parameter is reasonable to achieve an optimal dynamic range of the analog outputs whilst outputting the vector lengths X, Y and Z. However, it should not be used for certain applications (e.g. to detect offset values), due to the dynamic scaling may result in misleading data.</td></tr>
</table>

Parameter	Description
Vector Angle	The vector angles X, Y and Z (X-, Y- and Z-axis) are outputted. The scaling range is fixed, from -pi to pi. Note: Using this parameter is reasonable to monitor the phasing of the amplified search coil signals, e.g. if required during system optimization (see “6.5 Using the Phase Correction“ for further details).

5.3.6 Display Contrast

Function: Determines the contrast of the display. This setting is useful to adjust the contrast of the display, depending on the viewing angle.

Setting Type: Non-Critical

Menu System: Supported, generic setting 6 / 13

Parameters: 10 parameters selectable

Parameter	Description
10 %	10 % contrast of the display.
20 %	20 % contrast of the display.
30 %	30 % contrast of the display.
40 %	40 % contrast of the display.
50 %	50 % contrast of the display.
60 %	60 % contrast of the display.
70 %	70 % contrast of the display.
80 %	80 % contrast of the display.
90 %	90 % contrast of the display.
100 %	100 % contrast of the display.

5.3.7 Display Brightness

Function: Determines the brightness of the display. This setting is useful to adjust the brightness of the display, depending on the ambient light.

Setting Type: Non-Critical

Menu System: Supported, generic setting 7 / 13

Parameters: 4 parameters selectable

Parameter	Description
Off	No backlight of the display. Note 1: If this parameter is selected, the display is virtually unreadable. Therefore, using this parameter is only reasonable if the backlight of the display should be interfering, e.g. while a particular experiment is executed. Note 2: This parameter will never be recalled after system power is turned on, independently of the setting of 'Power On Mode'. Instead, if this parameter was selected when the system power was turned off, medium backlighting of the display is selected after system power is turned on.
Dark	Dark backlighting of the display.
Medium	Medium backlighting of the display.
Bright	Bright backlighting of the display.

5.3.8 Touch Screen Mode

Function: Determines the operating mode of the display's touch screen. This setting is useful to lock the touch screen, e.g. to prevent the use of the menu system while a particular experiment is executed.

Setting Type: Non-Critical

Menu System: Supported, generic setting 8 / 13

Parameters: 2 parameters selectable

Parameter	Description
Disabled	The touch screen is locked. Note: If this mode is selected, the menu system is inoperable until the next system power off-on cycle or until the touch screen is re-enabled over the USB interface by using the application software (see "5.8 Using the USB Interface" for further details).
Enabled	The touch screen is enabled. Note: This mode is always selected after system power is turned on, independently of the setting of 'Power On Mode'.

5.3.9 Audible Key Click

Function: Determines the mode of the audible key click of the menu system.

Setting Type: Non-Critical

Menu System: Supported, generic setting 9 / 13

Parameters: 2 parameters selectable

Parameter	Description
Disabled	No audible key click.
Enabled	Audible key click enabled.

5.3.10 Field Signals Magnitude

Function: Determines the magnitude of the field signals X, Y and Z.

The operator should never change the individual amplitudes of the field signals X, Y or Z because of this would change the factory tuning of the magnetic field. To reduce the magnetic field strength, e.g. if extremely large search coils are used or to turn off the magnetic field, the operator may use this setting to attenuate the tuned field signals in steps of 10 % down to zero.

Setting Type: Non-Critical

Menu System: Supported, generic setting 10 / 13

Parameters: 11 parameters selectable

Parameter	Description
Off	No magnetic field is generated by the coil frame.
10 %	10 % of the factory tuned magnetic field intensity is generated by the coil frame.
20 %	20 % of the factory tuned magnetic field intensity is generated by the coil frame.
30 %	30 % of the factory tuned magnetic field intensity is generated by the coil frame.
40 %	40 % of the factory tuned magnetic field intensity is generated by the coil frame.
50 %	50 % of the factory tuned magnetic field intensity is generated by the coil frame.
60 %	60 % of the factory tuned magnetic field intensity is generated by the coil frame.
70 %	70 % of the factory tuned magnetic field intensity is generated by the coil frame.
80 %	80 % of the factory tuned magnetic field intensity is generated by the coil frame.
90 %	90 % of the factory tuned magnetic field intensity is generated by the coil frame.
100 %	100 % of the factory tuned magnetic field intensity is generated by the coil frame.

5.3.11 Field Signal X / Y / Z

Function: Determines the respective amplitude of the field signals X1, X2, Y1, Y2, Z1 and Z2.

The amplitudes of the field signals are tuned at the factory to achieve the specified flux density and an optimal homogeneity of the AC magnetic field at the 3D-centre of the coil frame. How ever, if required for any reason, the amplitude of the field signals may be adjusted by the system administrator.

Caution: These are critical settings! You should never change these settings if you are not sure what you are doing. Applying inappropriate settings may cause inaccurate output data, may damage the system or may come for injuries to health caused by dangerous voltage levels.

Setting Type: Critical (system administrator only, application software required, see “5.8 Using the USB Interface” for further details).

Menu System: Not supported

Parameters: Numeric parameters, valid range from 0 to 4095

The setting of the field signals expects a numeric value in the range from 0 to 4095, corresponding to an amplitude of the respective field signal in the range from 0 V to 25.3 Vpp referenced to system ground. Note that the system’s power amplifiers have differential outputs, therefore the maximum amplitude of the respective field signal is up to 50.6 Vpp differential measured.

Notes:

As mentioned, the amplitudes of the field signals are tuned at the factory to achieve the specified flux density and an optimal homogeneity of the AC magnetic field at the 3D-centre of the coil frame. Therefore, the default value of these settings depends on the characteristics of the delivered coil frame. Under normal conditions, these values should never be changed. However, if required, read “4.5.3 Field Signals Tuning” for further details.

The operator may change the magnitude of the field signals in steps of 10 % down to zero to reduce the amplitudes of the field signals without changing the default value of these settings. See “5.3.10 Field Signals Magnitude“ for further details.

The field signals X2, Y2 and Z2 are reserved for future use, i.e. these field signals are not used for standard applications. The amplitudes of these field signals should always be set to 0 Volt, i.e. the setting of the field signals X2, Y2 and Z2 should always be 0.

5.3.12 Field Signal Phasing X2 / Y2 / Z2

Function: Determines the phasing of the field signals X2, Y2 and Z2 relative to the respective field signals X1, Y1 and Z1.

Setting Type: Critical (system administrator only, application software required, see “5.8 Using the USB Interface” for further details).

Menu System: Not supported

Parameters: 2 parameters selectable

Parameter	Description
Standard	0 degree phasing between the respective field signals.
Reversed	180 degree phasing between the respective field signals.

Note:

The field signals X2, Y2 and Z2 are reserved for future use, i.e. these field signals are not used for standard applications.

5.3.13 Field Signal Polarity X / Y / Z

Function: Determines the polarity of the field signals X, Y and Z.

The polarities of the field signals X, Y and Z are set at the factory to achieve a left-handed Cartesian coordinate system for the coil frame. However, the polarity of each field signal may be reversed individually by the system administrator. This allows the phase reversal of the respective field without the need for rewiring, which results in reversed polarity of the respective axis of all search coils.

Caution: These are critical settings! You should never change these settings if you are not sure what you are doing. Changing these settings may cause misleading output data.

See also “4.4.4 Coordinate System” and “4.7.3 Polarity” for further information.

Setting Type: Critical (system administrator only, application software required, see “5.8 Using the USB Interface” for further details).

Menu System: Not supported

Parameters: 2 parameters selectable

Parameter	Description
Standard	Standard polarity of the respective field signal.
Reversed	Reversed polarity of the respective field signal.

5.4 Channel Settings

This chapter describes all channel settings of the CS681.

Each of the eight channels of the CS681 may have assigned individual settings for the respective channel settings.

We distinguish two types of channel settings: The critical channel settings and the non-critical channel settings.

Critical channel settings concern those settings which have been adjusted specifically to your system at the factory. Therefore, the menu system of the CS681 don't supports the changing of critical settings and the operator may not change the critical settings in order to prevent accidental adjusting. If required, the system administrator may change the critical settings over the USB interface by using the delivered application software. See "5.8 Using the USB Interface" for further details.

Non-critical channel settings concern those settings which don't require system specific adjustment. Therefore, non-critical channel settings may be changed by the operator or the system administrator by using either the menu system or the application software.

Note:

Immediately after a channel setting changed, the system's output data will not be updated during a short period of time (120 ms typical).

Following is a detailed description of all channel settings. The respective default parameter of each setting is printed in bold characters.

5.4.1 Low Pass Filter

Function: Determines the mode of the low pass filter.

The vector lengths X, Y and Z may be low pass filtered before outputted and internally used for the trigonometric calculation of the angular data. The output data rate of the processed channels is 8 kHz, 4 kHz or 2 kHz (depending on the number of processed channels, see “5.3.2 Channels Processing” for further details). Should your application not need the full bandwidth of the respective output data rate, you may use the low pass filter to minimize noise on the output data.

Setting Type: Non-Critical

Menu System: Supported, channel setting 1 / 12

Parameters: 11 parameters selectable

Parameter	Description
Disabled	The low pass filter is disabled (bypassed).
Bessel 500 Hz	The low pass filter is enabled, characteristics: Bessel, 500 Hz, 4th order, IIR.
Bessel 200 Hz	The low pass filter is enabled, characteristics: Bessel, 200 Hz, 4th order, IIR.
Bessel 50 Hz	The low pass filter is enabled, characteristics: Bessel, 50 Hz, 4th order, IIR.
Butterworth 500 Hz	The low pass filter is enabled, characteristics: Butterworth, 500 Hz, 4th order, IIR.
Butterworth 200 Hz	The low pass filter is enabled, characteristics: Butterworth, 200 Hz, 4th order, IIR.
Butterworth 50 Hz	The low pass filter is enabled, characteristics: Butterworth, 50 Hz, 4th order, IIR.
Moving Average 8	The low pass filter is enabled, characteristics: Moving Average, 8 taps, FIR.
Moving Average 16	The low pass filter is enabled, characteristics: Moving Average, 16 taps, FIR.
Moving Average 32	The low pass filter is enabled, characteristics: Moving Average, 32 taps, FIR.

5.4.2 Gain Correction Mode

Function: Determines the mode of the gain correction.

The gain correction of the CS681 may be used to correct linearity errors of the output data.

If the gain correction is enabled, the vector lengths X, Y and Z respectively are multiplied by the respective gain correction value before outputted and internally used for the trigonometric calculation of the angular data.

Disabling the gain correction has the same effect as using a value of 1 for the gain correction values X, Y and Z.

See also “5.4.6 Gain Correction X / Y / Z” for further details.

Setting Type: Non-Critical

Menu System: Supported, channel setting 2 / 12

Parameters: 2 parameters selectable

Parameter	Description
Disabled	The gain correction is disabled (not in use).
Enabled	The gain correction is enabled. The vector lengths X, Y and Z respectively are multiplied by the respective gain correction value before outputted and internally used for the trigonometric calculation of the angular data.

5.4.3 Offset Correction Mode

Function: Determines the mode of the offset correction.

The offset correction of the CS681 may be used to cancel the unwanted effect of offset signals to the output data.

If the offset correction is enabled, the respective offset correction value is subtracted from the vector lengths X, Y and Z respectively before outputted and internally used for the trigonometric calculation of the angular data.

Disabling the offset correction has the same effect as using a value of 0 for the offset correction values X, Y and Z.

See also “5.4.7 Offset Correction X / Y / Z” for further details.

Setting Type: Non-Critical

Menu System: Supported, channel setting 3 / 12

Parameters: 2 parameters selectable

Parameter	Description
Disabled	The offset correction is disabled (not in use).
Enabled	The offset correction is enabled. The respective offset correction value is subtracted from the vector lengths X, Y and Z respectively before outputted and internally used for the trigonometric calculation of the angular data.

5.4.4 Search Coil Polarity

Function: Determines the polarity of the output data.

This setting may be used to reverse the polarity of the output data, which may be useful to reverse the polarity without the need for changing the physical connection polarity of the search coil.

See also “4.7.3 Polarity” for further details.

Setting Type: Non-Critical

Menu System: Supported, channel setting 4 / 12

Parameters: 2 parameters selectable

Parameter	Description
Standard	The polarity of the output data corresponds to the physical connection polarity of the search coil.
Reversed	The polarity of the output data is reversed to the physical connection polarity of the search coil

5.4.5 Preamplifier Gain

Function: Determines the gain of the preamplifier.

To achieve an optimal system performance, the level of the amplified search coil signal of a processed channel must be within a certain voltage range (operational range). This is achieved by setting the gain of the preamplifier to a reasonable value, depending on the characteristics of the connected search coil and the magnitude of the magnetic field.

See also “4.6 Preamplifier”, “4.7 Search Coils” and “5.3.10 Field Signals Magnitude” for further details.

Setting Type: Non-Critical

Menu System: Supported, channel setting 5 / 12

Parameters: Numeric parameter, valid range from 1 to 56

The setting of the gain of the preamplifier expects a numeric value in the range from 1 to 56. Note that this is a logarithmic setting.

The Level Indicator of the display indicates the actual level of the amplified search coil signal of the channel (see “5.1 Display Area”). The indicated level should always be in the range from 32 to 93 (operational range), independently of the position and angular orientation of the connected search coil. This ensures a good signal to noise ratio of the channel’s output data and prevents overdriving of the system’s ADC.

See also “6.6 Using an optimal Gain of the Preamplifier“ for further information.

Note:

It may be too laborious for the operator to determine a reasonable value for the gain of the preamplifier manually. Therefore the CS681 provides an automatic tuning of the gain of the preamplifier, see “5.6.1 Automatic Tuning of Preamplifier Gain” for further details.

5.4.6 Gain Correction X / Y / Z

Function: Determines the respective gain correction value X, Y and Z.

The gain correction of the CS681 may be used to correct linearity errors of the output data in a certain range, provided that the errors are constant in time. Inconstant errors, e.g. dynamically changing errors while moving the search coil, may not be corrected.

If the gain correction is enabled, the vector lengths X, Y and Z respectively are multiplied by the respective gain correction value before outputted and internally used for the trigonometric calculation of the angular data.

See also “5.4.2 Gain Correction Mode” for further details.

Setting Type: Non-Critical

Menu System: Supported, channel setting 6 … 8 / 12

Parameters: Numeric parameter, valid range from 0.0000 to 20.0000

The setting of the gain correction values X, Y and Z expects a numeric value in the range from 0 to 20. The default value is 1, resulting in the same effect as disabling the gain correction.

Set the gain correction values X, Y and Z to achieve identical values of the respective vector length X, Y and Z when the search coil is orthogonal aligned in the coil frame.

See also “6.4 Using the Gain Correction“ for further information.

Note:

It may be too laborious for the operator to determine reasonable values for the gain correction manually. Therefore the CS681 provides an automatic tuning of these values, see “5.6.3 Automatic Tuning of Gain Correction XYZ” for further details.

5.4.7 Offset Correction X / Y / Z

Function: Determines the respective offset correction value X, Y and Z.

The offset correction of the CS681 may be used to cancel the unwanted effect of offset signals to the output data, provided that the offset signals are constant in time. Inconstant offset signals, e.g. dynamically changing offset signals while moving the search coil, may not be canceled.

If the offset correction is enabled, the respective offset correction value is subtracted from the vector lengths X, Y and Z respectively before outputted and internally used for the trigonometric calculation of the angular data.

See also “5.4.3 Offset Correction Mode” for further details.

Setting Type: Non-Critical

Menu System: Supported, channel setting 9 … 11 / 12

Parameters: Numeric parameter, valid range from -250000 to 250000

The setting of the offset correction values X, Y and Z expects a numeric value in the range from -250000 to 250000. The default value is 0, resulting in the same effect as disabling the offset correction.

Set the offset correction values X, Y and Z to achieve zero values of the respective vector length X, Y and Z when the search coil is completely shielded.

See also “6.3 Using the Offset Correction“ for further information.

Note:

It may be too laborious for the operator to determine reasonable values for the offset correction manually. Therefore the CS681 provides an automatic tuning of these values, see “5.6.2 Automatic Tuning of Offset Correction XYZ” for further details.

5.4.8 Phase Correction Mode

Function: Determines the mode of the phase correction.

The phase correction of the CS681 is used to ensure correct determination of the sign of the respective vector length X, Y and Z.

If the phase correction is enabled, the phase correction values X, Y and Z respectively are used to ensure correct sign determination of the respective vector length X, Y and Z.

Disabling the phase correction results in incorrect sign determination of the respective vector length X, Y and Z and therefore will cause corrupted output data.

Caution: These are critical settings! You should never disable the phase correction. The phase correction is only temporarily disabled at the factory for testing purpose.

See also “5.4.9 Phase Correction X / Y / Z” for further details.

Setting Type: Critical (system administrator only, application software required, see “5.8 Using the USB Interface” for further details).

Menu System: Not supported

Parameters: 2 parameters selectable

Parameter	Description
Disabled	The phase correction is disabled (inactive).
Enabled	The phase correction is enabled (active).

5.4.9 Phase Correction X / Y / Z

Function: Determines the respective phase correction value X, Y and Z.

The phase correction of the CS681 is used to ensure correct determination of the sign of the respective vector length X, Y and Z. The CS681 detects the phasing of the amplified search coil signal relative to the phasing of the field signals to determine the sign of the respective vector length X, Y and Z. Without phase correction, extensive phase lags possibly cause incorrect sign determination.

If the phase correction is enabled, the phase correction values X, Y and Z respectively are used to ensure correct sign determination of the respective vector length X, Y and Z, provided that the phase lags are constant in time.

The phase correction values X, Y and Z respectively are tuned at the factory. If required, the values may be adjusted by the system administrator.

Caution: These are critical settings! You should never change these settings manually if you are not sure what you are doing. Applying inappropriate settings may cause misleading output data.

See also “5.4.8 Phase Correction Mode” for further details.

Setting Type: Critical (system administrator only, application software required, see “5.8 Using the USB Interface” for further details).

Menu System: Not supported

Parameters: Numeric parameters, valid range from 0 to 1023

The setting of the phase correction X, Y and Z expects a numeric value in the range from 0 to 1023, corresponding to a phase lag of the amplified search coil signal relative to the phasing of the respective field signal X, Y and Z in the range from 0 % to 99.9 %, i.e. to shift the respective vector angle X, Y and Z from –pi to pi.

See also “6.5 Using the Phase Correction“ for further information.

Note:

It may be too laborious for the system administrator to determine reasonable values for the phase correction manually. Therefore the CS681 provides an automatic tuning of these values, see “5.6.4 Automatic Tuning of Phase Correction” for further details.

5.5 Save and Recall Setup

The CS681 provides nonvolatile memory for ten user-specific setups and the factory settings (default values). Each setup contains the generic settings and the channel settings of all eight channels.

A setup may be saved or recalled by using either the menu system or the application software.

5.5.1 Save Setup

Saves all actual settings (i.e. the generic settings and the channel settings of all eight channels) in the selected user memory.

Note:

While saving the setup, the system's output data will not be updated during a short period of time (370 ms typical).

5.5.2 Recall Setup

Recalls all settings (i.e. the generic settings and the channel settings of all eight channels) from the selected user memory or the factory settings (default values) respectively and updates the behavior of the CS681 according to the recalled settings.

Note:

While recalling the setup, the system's output data will not be updated during a short period of time (1.25 s typical).

5.6 Automatic Tuning

This chapter describes the use of the automatic tuning modes.

In order to achieve optimal system performance, it is recommended to adjust the relevant channel settings after a search coil has been connected to the preamplifier. To determine reasonable values for these settings manually may be too laborious for the operator. Therefore the CS681 provides four automatic tuning modes to support the operator by automatically detecting and applying the best fitted settings:

- Automatic tuning of the preamplifier gain
- Automatic tuning of the offset correction values
- Automatic tuning of the gain correction values
- Automatic tuning of the phase correction values

Automatic tuning may be initiated by the menu system, either from the generic settings or the channel settings. If automatic tuning was initiated from the generic settings, all eight channels will be tuned sequentially, otherwise only the concerning channel will be tuned.

Automatic tuning may also be initiated over the USB interface by using the delivered application software, see “5.8 Using the USB Interface” for further details.

5.6.1 Automatic Tuning of Preamplifier Gain

This section describes the use of automatic tuning to achieve an optimal setting for the gain of the preamplifier.

To achieve an optimal system performance, the level of the amplified search coil signal must be within a certain voltage range (operational range, see also “5.1 Display Area“). This is achieved by setting the gain of the concerning channel of the preamplifier to a reasonable value. The optimal setting for the gain depends on the characteristics of the connected search coil and the magnitude of the magnetic field. See also “5.4.5 Preamplifier Gain“ and “6.6 Using an optimal Gain of the Preamplifier“ for further information.

It may be too laborious for the operator to determine a reasonable value for the gain of the preamplifier manually. Therefore it is suggested to run automatic tuning to determine an optimal value.

Function

Automatic tuning of the preamplifier gain automatically determines the optimal gain setting of the preamplifier for the respective channel. Hereafter, the determined gain setting is applied.

Process

1. Connect the used search coil to the preamplifier.
2. Place the search coil at that position within the coil frame, which will be used later during the experiment. The search coil must be mounted with a holder to ensure stable positioning during automatic tuning is running.
3. Start automatic tuning of the preamplifier gain for the used channel. Automatic tuning analyzes the amplified search coil signal to determine the optimal gain setting of the preamplifier for the respective channel. To achieve reliable results, prevent any movements of the search coil until automatic tuning is completed.

Example

To automatically tune the gain of the preamplifier of channel 6 to an optimal suited value, follow the steps listed below.

Note the section of the display with the line which indicates the actual level of the amplified search coil signal of channel 6 in the figure below. <100> indicates that the level is too high, therefore the system's ADC may be overdriven and the output data of this channel may be corrupted! We will now automatically tune the gain of the preamplifier for this channel in order to optimize the level of the amplified search coil signal.

We want to automatically tune the gain of the preamplifier of channel 6. Therefore, touch the framed section of the display to activate the menu system in order to control the settings of channel 6:

The Menu System is activated. Note that the previously selected channel setting is displayed, in this example 'Low Pass Filter':

Press the keys ≪ or ≫ to scroll through the settings until the setting ‘Automatic Tuning’ is displayed. Note the indicator of the selected setting / number of settings: The setting ‘Automatic Tuning’ is the 12. setting of total 12 settings:

Press the key Enter to switch to the parameter selection of the setting, i.e. the parameters will be selected:

Press the keys ≪ or ≫ to scroll through the parameters of the setting until the parameter ‘Preamplifier Gain’ is displayed. Note the indicator of the selected parameter / number of parameters: The parameter ‘Preamplifier Gain’ is the 1. parameter of total 4 parameters for this setting:

Press the key Enter to continue…

Automatic tuning displays a startup message:

If not already done, connect now a search coil to channel 6 of the preamplifier. Place the search coil at the position within the coil frame, which will be used later during your experiments. The search coil must be mounted with a holder to ensure stable mounting during automatic tuning, due to automatic tuning presumes no movements of the search coil during the process.

Note the lower section of the display. Automatic tuning of the gain don't presumes a specific orientation of the search coil.

Once you are ready, press Start to run automatic tuning.

Automatic tuning is running and determines the optimal value for the gain of the preamplifier:

To achieve a reliable value, automatic tuning presumes no movements of the search coil during the process is running. Wait until the process is terminated.

Once automatic tuning is terminated, the menu system is deactivated:

The determined value for the gain of the preamplifier is applied. Note the section of the display with the line which indicates the actual level of the amplified search coil signal of channel 6 in the figure above. The indicated level is now lower and within the operational range.

5.6.2 Automatic Tuning of Offset Correction XYZ

This section describes the use of automatic tuning to achieve optimal settings for the offset correction values X, Y and Z.

The offset correction of the CS681 may be used to cancel the unwanted effect of offset signals to the output data. If the offset correction is enabled, the respective offset correction value is subtracted from the vector lengths X, Y and Z respectively before outputted and internally used for the trigonometric calculation of the angular data. See also “5.4.7 Offset Correction X / Y / Z“ and “6.3 Using the Offset Correction“ for further information.

It may be too laborious for the operator to determine reasonable values for the offset correction manually. Therefore it is suggested to run automatic tuning to determine the optimal values.

Function

Automatic tuning of the offset correction XYZ automatically determines the optimal offset correction values X, Y and Z for the respective channel. Hereafter the determined offset correction values are applied and the offset correction is enabled.

Process

1. Connect the used search coil to the preamplifier.
2. Place the search coil at that position within the coil frame, which will be used later during the experiment. The search coil must be mounted with a holder to ensure stable positioning during automatic tuning is running.
3. Shield the search coil completely, such that there is typically no signal from the search coil. Thus, the respective remaining signal (if any) is the unwanted offset signal which is irradiated and will be analyzed during automatic tuning.
4. Start automatic tuning of the offset correction XYZ for the used channel. Automatic tuning analyzes the resulting vector lengths X, Y and Z to determine the optimal offset correction values X, Y and Z for the respective channel. To achieve reliable results, prevent any movements of the search coil until automatic tuning is completed.

Example

To automatically tune the offset correction values X, Y and Z respectively of all eight channels to optimal suited values, follow the steps listed below:

We want to automatically tune the offset correction values X, Y and Z respectively of all eight channels. Therefore, touch the framed section of the display to activate the menu system in order to control the generic settings:

The menu system is activated. Note that the previously selected generic setting is displayed, in this example ‘Audible Key Click’:

Press the keys ⋘ or ⋙ to scroll through the settings until the setting ‘Automatic Tuning’ is displayed. Note the indicator of the selected setting / number of settings: The setting ‘Automatic Tuning’ is the 13. setting of total 13 settings:

Press the key Enter to switch to the parameter selection of the setting, i.e. the parameters will be selected:

Press the keys ≪ or ≫ to scroll through the parameters of the setting until the parameter ‘Offset Correction XYZ’ is displayed. Note the indicator of the selected parameter / number of parameters: The parameter ‘Offset Correction XYZ’ is the 2. parameter of total 4 parameters for this setting:

Press the key Enter to continue…

Automatic tuning displays a startup message:

If not already done, connect now the search coils to the preamplifier. Place the search coils at the position within the coil frame which will be used later during your experiments. The search coils must be mounted with a holder to ensure stable mounting during automatic tuning, due to automatic tuning presumes no movements of the search coils during the process.

Shield the search coils completely, such that there is typically no signal from the search coils. Thus, the respective remaining signal (if any) is the unwanted offset signal which is irradiated and will be analyzed during automatic tuning.

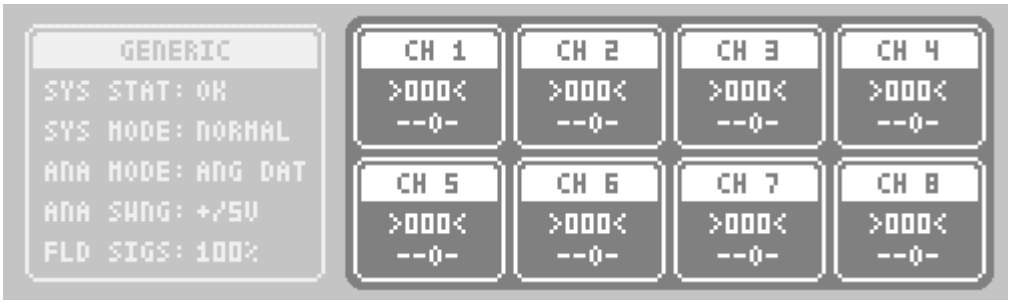
Note the lower section of the display. Automatic tuning of the offset correction don't presumes a specific orientation of the search coils.

Once you are ready, press Start to run automatic tuning.

Automatic tuning is running and determines the respective optimal offset correction values:

To achieve reliable values, automatic tuning presumes no movements of the search coils during the process is running. Wait until the process is terminated.

Once automatic tuning is terminated, the menu system is deactivated:



The determined respective offset correction values are applied and the offset correction of all channels is enabled (note the sections of the display which indicate the actual setting of the offset correction mode).

5.6.3 Automatic Tuning of Gain Correction XYZ

This section describes the use of automatic tuning to achieve optimal settings for the gain correction values X, Y and Z.

The gain correction of the CS681 may be used to correct linearity errors of the output data in a certain range. If the gain correction is enabled, the vector lengths X, Y and Z respectively are multiplied by the respective gain correction value before outputted and internally used for the trigonometric calculation of the angular data. See also “5.4.6 Gain Correction X / Y / Z“ and “6.4 Using the Gain Correction“ for further information.

It may be too laborious for the operator to determine reasonable values for the gain correction manually. Therefore it is suggested to run automatic tuning to determine the optimal values.

Function

Automatic tuning of the gain correction XYZ automatically determines the optimal gain correction values X, Y and Z for the respective channel. Hereafter the determined gain correction values are applied and the gain correction is enabled.

Process

1. Connect the used search coil to the preamplifier.
2. Place the search coil at that position within the coil frame, which will be used later during the experiment. The search coil must be mounted with a holder to ensure stable positioning during automatic tuning is running.
3. Align the orientation of the search coil to exactly 45° in the horizontal plane and 225° in the vertical plane. The orientation of the search coil must remain stable during automatic tuning is running.
4. Start automatic tuning of the gain correction XYZ for the used channel. Automatic tuning analyzes the resulting vector length X, Y and Z respectively and determines the required gain correction values X, Y and Z. To achieve reliable results, prevent any movements of the search coil until automatic tuning is completed.

Example

To automatically tune the gain correction values X, Y and Z respectively of channel 6 to optimal suited values, follow the steps listed below:

We want to automatically tune the gain correction values X, Y and Z respectively of channel 6 of the preamplifier. Therefore, touch the framed section of the display to activate the menu system in order to control the settings of channel 6:

The menu system is activated. Note that the previously selected channel setting is displayed, in this example ‘Preamplifier Gain’:

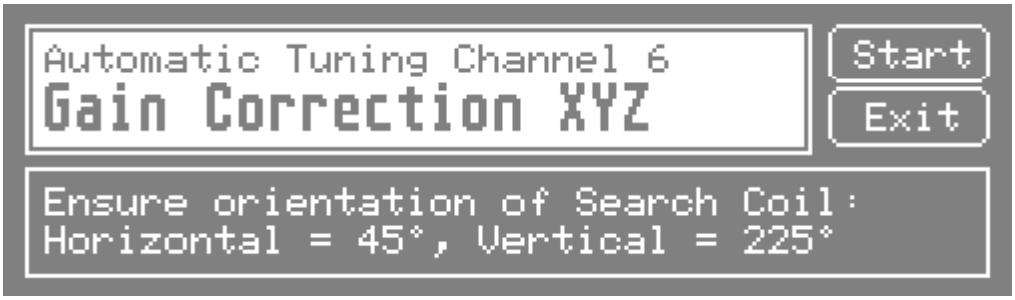
Press the keys ⋘ or ⋙ to scroll through the settings until the setting ‘Automatic Tuning’ is displayed. Note the indicator of the selected setting / number of settings: The setting ‘Automatic Tuning’ is the 12. setting of total 12 settings:

Press the key Enter to switch to the parameter selection of the setting, i.e. the parameters will be selected:

Press the keys ≪ or ≫ to scroll through the parameters of the setting until the parameter ‘Gain Correction XYZ’ is displayed. Note the indicator of the selected parameter / number of parameters: The parameter ‘Gain Correction XYZ’ is the 3. parameter of total 4 parameters for this setting:

Press the key Enter to continue…

Automatic tuning displays a startup message:



If not already done, connect now a search coil to channel 6 of the preamplifier. Place the search coil at the position within the coil frame which will be used later during your experiments. The search coil must be mounted with a holder to ensure stable mounting during automatic tuning, due to automatic tuning presumes no movements of the search coil during the process.

Align the orientation of the search coil to exactly 45° in the horizontal plane and 225° in the vertical plane. Automatic tuning will analyze the resulting vector length X, Y and Z respectively and determine the required gain correction values X, Y and Z to achieve correct output data.

Note the lower section of the display. Automatic tuning of the gain correction presumes the specified orientation of the search coil.

Once you are ready, press Start to run automatic tuning.

Automatic tuning is running and determines the respective optimal gain correction values:

To achieve reliable values, automatic tuning presumes no movements of the search coil during the process is running. Wait until the process is terminated.

Once automatic tuning is terminated, the menu system is deactivated:

The determined respective gain correction values are applied and the gain correction for channel 6 is enabled (note the section of the display which indicates the actual setting of the gain correction mode of channel 6).

5.6.4 Automatic Tuning of Phase Correction XYZ

This section describes the use of automatic tuning to achieve optimal settings for the phase correction values X, Y and Z.

The phase correction of the CS681 is used to ensure correct determination of the sign of the respective vector length X, Y and Z by detecting the phasing of the amplified search coil signal relative to the phasing of the field signals. If the phase correction is enabled, the phase correction values X, Y and Z respectively are used to ensure correct sign determination of the respective vector length X, Y and Z. See also “5.4.9 Phase Correction X / Y / Z“ and “6.5 Using the Phase Correction“ for further information.

It may be too laborious for the operator to determine reasonable values for the phase correction manually. Therefore it is suggested to run automatic tuning to determine the optimal values.

Function

Automatic tuning of the phase correction XYZ automatically determines the optimal phase correction values X, Y and Z for the respective channel. Hereafter the determined phase correction values are applied and the phase correction is enabled.

Process

1. Connect the used search coil to the preamplifier.
2. Place the search coil at that position within the coil frame, which will be used later during the experiment. The search coil must be mounted with a holder to ensure stable positioning during automatic tuning is running.
3. Align the orientation of the search coil to approximately 45° in the horizontal plane and 225° in the vertical plane. The orientation of the search coil must remain stable during automatic tuning is running.
4. Start automatic tuning of the phase correction XYZ for the used channel. Automatic tuning analyzes the resulting vector angle X, Y and Z respectively and determines the required phase correction values X, Y and Z. To achieve reliable results, prevent any movements of the search coil until automatic tuning is completed.

Example

To automatically tune the phase correction values X, Y and Z respectively of channel 6 to optimal suited values, follow the steps listed below:

We want to automatically tune the phase correction values X, Y and Z respectively of channel 6 of the preamplifier. Therefore, touch the framed section of the display to activate the menu system in order to control the settings of channel 6:

The menu system is activated. Note that the previously selected channel setting is displayed, in this example ‘Low Pass Filter’:

Press the keys ⋘ or ⋙ to scroll through the settings until the setting ‘Automatic Tuning’ is displayed. Note the indicator of the selected setting / number of settings: The setting ‘Automatic Tuning’ is the 12. setting of total 12 settings:

Press the key Enter to switch to the parameter selection of the setting, i.e. the parameters will be selected:

Press the keys ⩽ or ⩾ to scroll through the parameters of the setting until the parameter ‘Phase Correction XYZ’ is displayed. Note the indicator of the selected parameter / number of parameters: The parameter ‘Phase Correction XYZ’ is the 4. parameter of total 4 parameters for this setting:

Press the key Enter to continue…

Automatic tuning displays a startup message:

If not already done, connect now a search coil to channel 6 of the preamplifier. Place the search coil at the position within the coil frame which will be used later during your experiments. The search coil must be mounted with a holder to ensure stable mounting during automatic tuning, due to automatic tuning presumes no movements of the search coil during the process.

Align the orientation of the search coil to approximately 45° in the horizontal plane and 225° in the vertical plane. Automatic tuning will analyze the resulting vector angle X, Y and Z respectively and determine the required phase correction values X, Y and Z respectively to achieve correct output data.

Note the lower section of the display. Automatic tuning of the phase correction presumes the specified orientation of the search coil.

Once you are ready, press Start to run automatic tuning.

Automatic tuning is running and determines the respective optimal phase correction values:

To achieve reliable values, automatic tuning presumes no movements of the search coil during the process is running. Wait until the process is terminated.

Once automatic tuning is terminated, the menu system is deactivated:

The determined respective phase correction values are applied and the phase correction for channel 6 is enabled. Note the section of the display which indicates the actual settings of channel 6. The phase correction mode is a critical setting and not accessible over the menu system, therefore no changing is apparent in this section.

5.7 Using the Analog Outputs

This section describes the use of the analog outputs of the CS681.

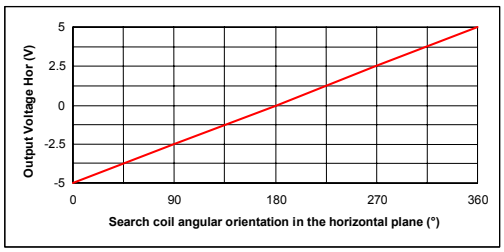
You may optionally use an external data acquisition system (e.g. an analog data acquisition board for a PC) to capture the analog output signals of the CS681 (see connector 'Analog Outputs', "4.3.2 Connectors and Control Elements"). The used data acquisition system should comply minimum requirements to ensure reliable results with the required precision (see "4.8 External Data Acquisition ").

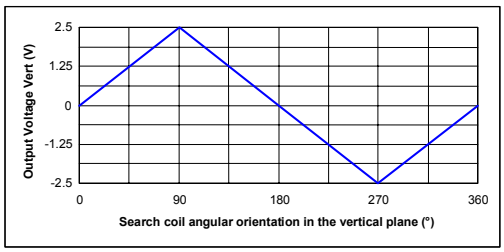
The CS681 provides 24 digital to analog converters (DAC) to provide analog output data. Each DAC has a resolution of 14 Bits. The output impedance of the analog outputs is 50 Ohm. The update rate of the analog outputs depends on the selected number of processed channels (see "5.3.2 Channels Processing" for further details). The output voltage of non-processed channels is set to 0 V.

The format of the analog outputs is selectable by the operator. Depending on the selected format, two or three parameters per channel are outputted. See "5.3.5 Analog Outputs Mode" for further details.

The voltage swing of the analog outputs is selectable by the operator This allows the optimal matching of the voltage range of the analog outputs to the input voltage range of the used data acquisition system. See "5.3.4 Analog Outputs Swing" for further details.

Typical progression of the analog outputs (mode Angular Data, swing ±5 Volt):





Notes:

- While saving or recalling a setup or immediately after a setting of the CS681 has been changed by the operator, the analog outputs will not be updated during a short period of time (370 ms typical while saving a setup, 1.25 s typical while recalling a setup, 120 ms typical after changing a setting).
- It may be helpful to use the test signals generated by the CS681 (see "5.3.1 System Mode") to get familiar with the settings concerning the analog outputs. This may also be useful during the setup of an external data acquisition system.

5.8 Using the USB Interface

This section describes the use of the USB interface of the CS681.

The system's USB interface continuously transmits the output data and may be used to control the settings of the system. You may optionally connect an external computer to the system's USB interface. The used computer should comply minimum requirements to ensure reliable operation (see "4.9 External Computer").

It is recommended to connect the USB interface of the CS681 directly to an available USB port of the computer, i.e. do not use an external USB hub.

Note that the delivered software must be installed before the CS681 is connected for the first time to the computer. See "4.9.1 Software Installation" for further details.

An application software (CS681Tools.exe) is part of the delivery. The self-explanatory software may control the system and may be used to visualize, analyze and capture the system's output data.

Also included is an ActiveX control (priCS681.ocx), which allows an application software (e.g. written in Visual Basic or a LabVIEW VI) the straightforward communication with the CS681 over the USB. The ActiveX control comes with documentation (priCS681.chm) and examples (LabVIEW VI and Visual Basic source code). The examples provide a quick overview of the ActiveX control and are highly recommended as an introduction to the control's capabilities.

Notes:

- While saving or recalling a setup or immediately after a setting of the CS681 has been changed by the operator, the USB interface will not transmit data during a short period of time (370 ms typical while saving a setup, 1.25 s typical while recalling a setup, 120 ms typical after changing a setting).
- It may be helpful to use the test signals generated by the CS681 (see "5.3.1 System Mode") to get familiar with the features and the handling of the delivered application software as well as during the deployment of an application software using the ActiveX control.

6.0 System Optimization

This chapter describes the system optimization if the CS681 is operated under difficult conditions.

Under normal conditions, the CS 681 achieves the high performance as specified in the technical data. To avoid possible problems if the system is operated under difficult conditions, follow the recommendations of this chapter.

6.1 Optimizing the Magnetic Field Quality

Consider the following points to maintain an optimal quality of the magnetic field:

- Avoid large metallic parts (e.g. iron, aluminum, copper, reinforced concrete etc.) inside of or near to the coil frame to prevent distortions of the magnetic field which would result in nonlinear output data.

- Avoid electrical devices which radiate an AC magnetic field (e.g. CRTs, electric motors, transmitters, computers, etc.) inside of or near to the coil frame. The radiation may interfere with the system's magnetic field, resulting in nonlinear and / or noisy output data.

- Prevent crosstalk between the field signals. Preferably use only the delivered cable to connect the matching-box of the coil frame. If you should require an extension cable, use only high quality cables, i.e. shielded twisted pairs for each pair of the differential field signals. Keep the cables as short as practicable. Should the coil frame be operated on a turntable, see Appendix, "Slip Ring Wiring" for wiring details. Improper cabling and / or inappropriate slip ring wiring may result in crosstalk between the field signals, resulting in nonlinear and / or jumping output data.

- Minimize inductive coupling between the X, Y and Z Frames. A non-orthogonal geometry of the coil frame and / or electroconductive material near to the coil frame may increase the inductive coupling between the X, Y and Z Frames. This may result in nonlinear and / or jumping output data.

- Do not separately change the amplitude of the field signals X, Y and Z if not necessary. The amplitudes of the field signals are tuned at the factory to achieve the specified flux density and an optimal homogeneity of the AC magnetic field at the 3D-centre of the coil frame. If you should want to reduce the magnetic field strength, preferably change the magnitude of the tuned field signals in steps of 10 % down to zero (see "5.3.10 Field Signals Magnitude").

- If you own several systems, please keep in mind that each system was tuned at the factory and therefore the default values of some settings depend on the characteristics of the respective delivered coil frame. Note the serial numbers of the main units and the coil frames respectively and connect only the corresponding devices with identical serial numbers.

6.2 Optimizing the Search Coil Signal Quality

Consider the following points to maintain an optimal quality of the search coil signal:

- The characteristics of the used search coils should comply with the specification listed in the technical data of the CS681.

- The effective area of the used search coils should be as large as practicable to optimize the signal to noise ratio.

- The DC resistance of the used search coils should be as low as possible to optimize the signal to noise ratio and to minimize linearity errors. Therefore, the search coil should consist of a material with a low specific resistance (e.g. copper or silver), the length of the connection wires should be as short as practicable and the cross section of the wires should be as large as practicable.

- Twist the two connection wires of the search coils as tight as any possible and keep their length as short as practicable to minimize irradiation of unwanted offset signals (see additional description below). Irradiated signals may result in shifted, nonlinear, noisy or jumping output data.

- Prevent any additional interconnections between the search coils and the preamplifier to minimize irradiation of unwanted offset signals (see additional description below). Irradiated signals may result in shifted, nonlinear, noisy or jumping output data.

- Prevent radiation from the coil frame to the preamplifier. Preferably mount the preamplifier at least 1 m from the coil frame to minimize irradiation (see additional description below). Irradiated signals may result in shifted, nonlinear or jumping output data.

- Prevent crosstalk from the field signals to the amplified search coil signals. Preferably use only the delivered cable to connect the preamplifier. If you should require an extension cable, use only high quality cables, i.e. shielded twisted pairs for each pair of the amplified search coil signals. Keep the cables as short as practicable. Should the preamplifier be operated on a turntable, see Appendix, “Slip Ring Wiring” for wiring details. Improper cabling and / or inappropriate slip ring wiring may result in crosstalk from the field signals to the amplified search coil signals, resulting in shifted, nonlinear or jumping output data.

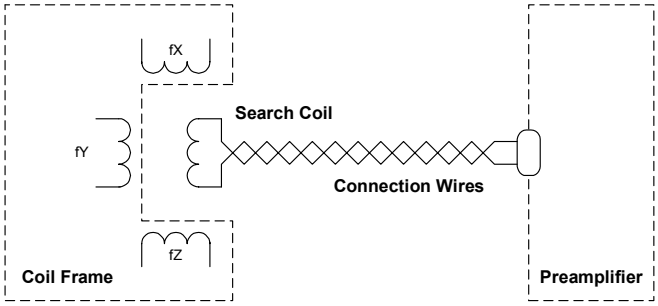
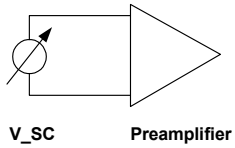
- Preferably use the screw-on flange which shields the search coil connectors of the preamplifier to minimize irradiation. Irradiated signals may result in shifted, nonlinear or jumping output data.

- Preferably operate the search coils at the 3D-centre of the coil frame to optimize the linearity of the output data.

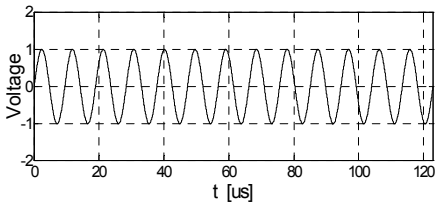
Search Coil Wiring

Following are some examples to illustrate the effect of the wiring of the search coil on the system's outputs Angular Data α (horizontal plane) and β (vertical plane), where always the same search coil is used with an angular orientation of 0° in the horizontal plane and 180° in the vertical plane.

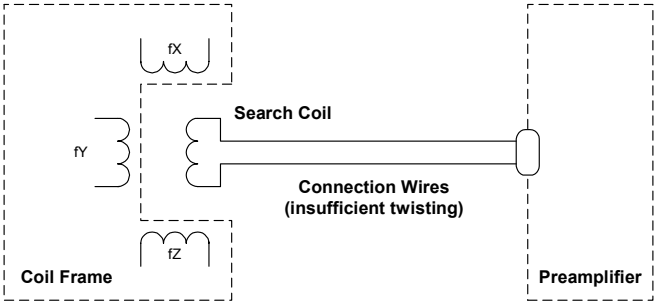
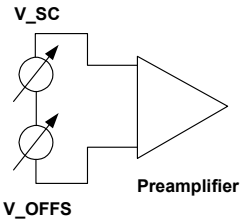
Optimal Wiring of the Search Coil:

Wiring Diagram	Equivalent Circuit Diagram
	
The connection Wires of the search coil are tight twisted. No interconnection is used between the search coil and the input of the preamplifier.	The input signal of the preamplifier consists only of the search coil signal (V_SC).

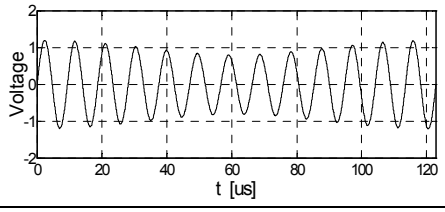
This wiring results in an optimal preamplifier input signal and correct system output of the angles α and β:

α	β	Induced Search Coil Signal	Vector Lengths
0°	180°		X 100000 Y 100 (noise) Z 100 (noise)

Poor Wiring of the Search Coil – Insufficient twisting:

Wiring Diagram	Equivalent Circuit Diagram
	
The connection Wires of the search coil are **not or insufficient twisted**. An offset signal is picked-up by the connection wires, e.g. a signal from Field Coil Y.	The input signal of the preamplifier consists of the search coil signal V_SC plus the offset signal V_OFFS..

Insufficient twisting of the connection wires may cause an offset signal V_OFFS. In this example, V_OFFS is caused by radiation of the Field Coil Y to the connection wires of the search coil, resulting in an incorrect system output of the angle α:

α	β	Induced Search Coil Signal	Vector Lengths
11°	180°		X 98163 Y 19081 (offset) Z 100 (noise)

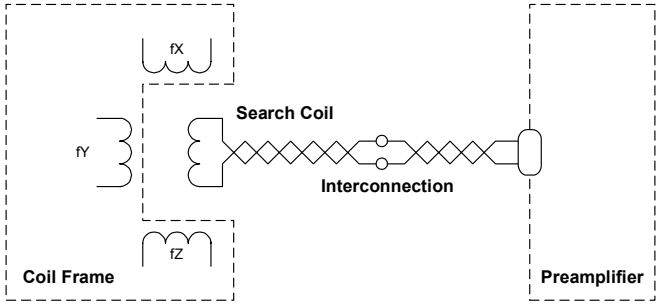
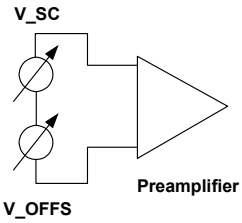
Note:

Depending on the source of the offset signal, a resulting offset signal may lead to offset and / or noise on the system's output data.

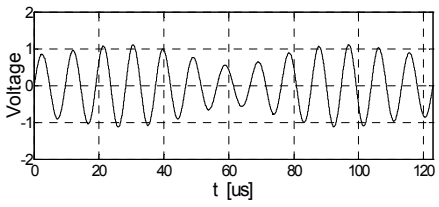
If the offset signal is caused by the magnetic field of the system, the offset signal may lead to offsets on the system's output data.

If the offset signal is caused by irradiation of a third-party device (e.g. an electric motor or a CRT), the offset signal may lead to noisy system outputs, provided that the irradiated frequencies are in the spectrum of the magnetic field frequencies of the system.

Poor Wiring of the Search Coil – Interconnection:

Wiring Diagram	Equivalent Circuit Diagram
	
An **interconnection** is used between the search coil and the input of the preamplifier. An offset signal is picked-up by the interconnection, e.g. a signal from the coil frame.	The input signal of the preamplifier consists of the search coil signal V_SC plus the offset signal V_OFFS..

An interconnection between the search coil and the input of the preamplifier may cause an offset signal V_OFFS. In this example, V_OFFS is caused by radiation of the coil frame to the interconnection, resulting in an incorrect system output of the angles α and β:

α	β	Induced Search Coil Signal	Vector Lengths
9°	167°		X 96237 Y 15243 (offset) Z -22495 (offset)

Note:

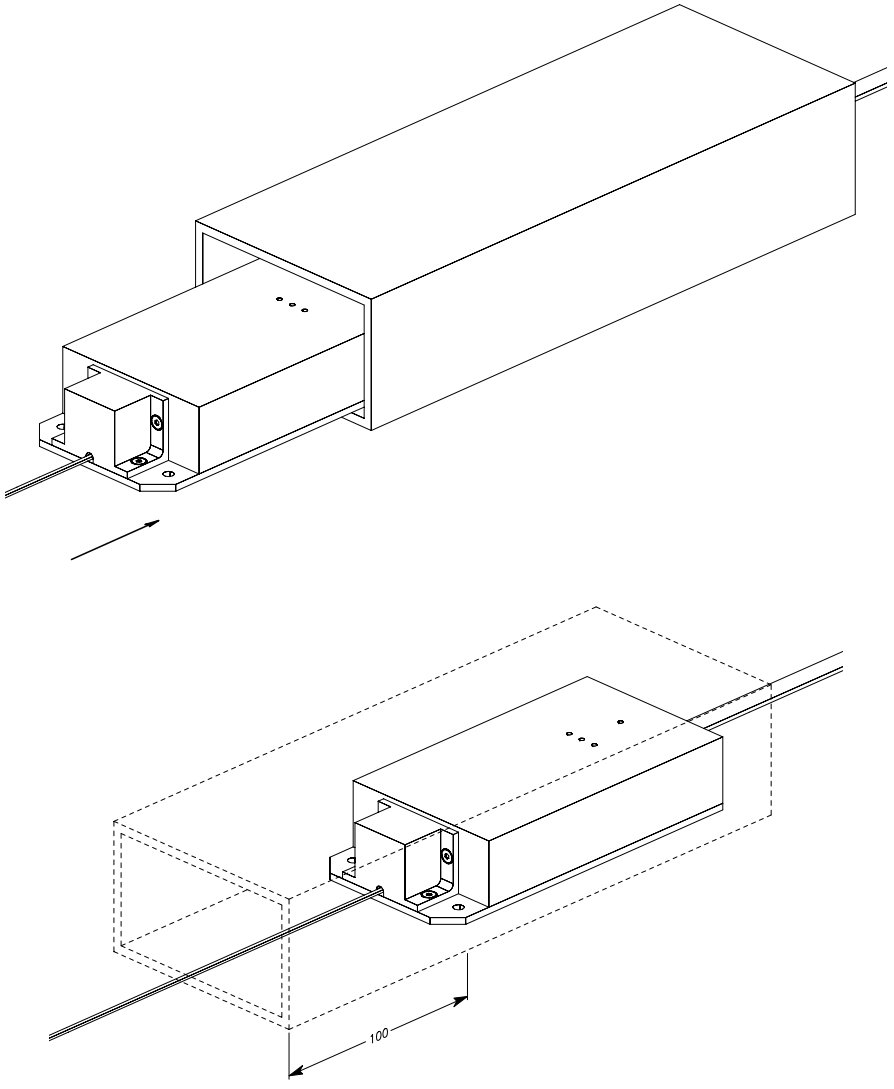
Depending on the source of the offset signal, a resulting offset signal may lead to offset and / or noise on the system's output data.

If the offset signal is caused by the magnetic field of the system, the offset signal may lead to offsets on the system's output data.

If the offset signal is caused by irradiation of a third-party device (e.g. an electric motor or a CRT), the offset signal may lead to noisy system outputs, provided that the irradiated frequencies are in the spectrum of the magnetic field frequencies of the system.

Additional shielding of the Preamplifier

Preferably the preamplifier should be mounted at least 1 m from the coil frame to minimize irradiation. Thus, the cabinet of the preamplifier provides adequate irradiation attenuation to prevent stray pick-up of unwanted offset signals. If it is necessary for any reason to mount the preamplifier close to the coil frame and if you suspect irradiated signals, an aluminium square pipe may be used for additional shielding of the preamplifier. For example, a 100 x 50 x 4 mm cross square pipe with a length of 330 mm provides optimal shielding. However, mounting these components close to the coil frame may result in distortions of the magnetic field, which may degrade the linearity of the output data. Therefore, as mentioned above, if any possible the preamplifier should be mounted at least 1 m from the coil frame to avoid problems.



6.3 Using the Offset Correction

Under optimal conditions, the search coil signal consists only of the voltage picked-up by the search coil. Under difficult conditions, unwanted offset signals may be irradiated. See “6.2 Optimizing the Search Coil Signal Quality” to prevent this if possible.

The offset correction of the CS681 may be used to cancel the effect of the unwanted offset signal to the output data, provided that the amplitude of the offset signal is constant in time. An inconstant offset signal, e.g. a changing of the amplitude of the offset signal while moving the search coil, may not be canceled. If the offset correction is enabled, the respective offset correction value X, Y and Z is subtracted from the vector lengths X, Y and Z respectively before outputted and internally used for the trigonometric calculation of the angular data. See also “5.4.7 Offset Correction X / Y / Z” for further information.

To determine the offset correction values X, Y and Z respectively, place the search coil at the position within the coil frame which will be used later during your experiments. Shield the search coil completely, such that there is typically no signal from the search coil. Thus, the remaining signal (if any) is the unwanted offset signal which is irradiated and therefore the actually outputted vector lengths X, Y and Z correspond to the correction values X, Y and Z respectively required for the offset correction. Note that the offset correction and the gain correction must be disabled at this time to avoid false results caused by eventually applied correction values. The table below depicts some examples under various conditions:

Conditions	Vector Lengths	α	β
Optimal conditions, i.e. the amplified search coil signal consists only of the search coil signal.	X 60402 Y -71985 Z 34202	130°	200°
An offset signal is irradiated, the amplified search coil signal consists of the search coil signal plus the offset signal. **The offset correction is disabled.**	X 40402 Y -86985 Z 44202	115°	205°
The search coil is completely shielded, the remaining amplified search coil signal consists only of the irradiated offset signal.	X -20000 Y -15000 Z 10000	37°	202°
An offset signal is irradiated, the amplified search coil signal consists of the search coil signal plus the offset signal. **The offset correction is enabled**, using the determined offset correction values.	X 60402 Y -71985 Z 34202	130°	200°

The procedure described above to determine and set the offset correction values manually may be too laborious for the operator. Therefore it is strongly recommended to run automatic tuning to determine the optimal values. See “5.6.2 Automatic Tuning of Offset Correction XYZ” for further details.

6.4 Using the Gain Correction

Under optimal conditions, the system's output data is proportional to the horizontal and vertical angular displacements of the search coil relative to the system's reference frame. Under difficult conditions, the linearity of the output data may be degraded. See "6.1 Optimizing the Magnetic Field Quality" and "6.2 Optimizing the Search Coil Signal Quality" to prevent this if possible.

The gain correction of the CS681 may be used to correct linearity errors of the output data in a certain range, provided that the errors are constant in time. Inconstant errors, e.g. dynamically changing errors while moving the search coil, may not be corrected. If the gain correction is enabled, the vector lengths X, Y and Z respectively are multiplied by the respective gain correction value before outputted and internally used for the trigonometric calculation of the angular data. See also "5.4.6 Gain Correction X / Y / Z" for further information.

To determine the gain correction values X, Y and Z respectively, place the search coil at the position within the coil frame which will be used later during your experiments. Align the orientation of the search coil to exactly 45° in the horizontal plane and 225° in the vertical plane. Thus, without any linearity errors, the outputted vector lengths X, Y and Z will be in a ratio of 1 : 1 : 1.41421 (X : Y : Z). Therefore, the deviation of the actually outputted ratio of the vector lengths X, Y and Z to the expected ratio results the required gain correction values. Note that the gain correction and the offset correction must be disabled at this time to avoid false results caused by eventually applied correction values.

The table below depicts some examples under various conditions:

Conditions	Vector Lengths	α	β
Optimal conditions, i.e. no linearity errors.	X 60402 Y -71985 Z 34202	130°	200°
Linearity errors caused by magnetic field distortion. **The gain correction is disabled.**	X 75503 Y -57588 Z 40238	143°	203°
Linearity errors caused by magnetic field distortion. **The gain correction is enabled**, using the determined offset correction values, i.e.: **X = 0.8,** **Y = 1.25,** **Z = 0.85**	X 60402 Y -71985 Z 34202	130°	200°

The procedure described above to determine and set the gain correction values manually may be too laborious for the operator. Therefore it is strongly recommended to run automatic tuning to determine the optimal values. See "5.6.3 Automatic Tuning of Gain Correction" for further details.

6.5 Using the Phase Correction

The CS681 detects the phasing of the amplified search coil signal relative to the phasing of the field signals. The detected phase lags are the vector angles X, Y and Z respectively in the range from –pi to pi, which are used to determine the sign of the vector lengths X, Y and Z respectively. The signs of the respective vector lengths are determined by adopting the signs of the respective vector angles.

Difficult conditions may cause extensive phase lags, possibly resulting in incorrect sign determination of the vector lengths. See “6.1 Optimizing the Magnetic Field Quality” and “6.2 Optimizing the Search Coil Signal Quality” to prevent this if possible. However, the phase correction of the CS681 is used to ensure correct determination of the signs of the vector lengths. If the phase correction is enabled, the phase correction values X, Y and Z respectively are used to ensure correct sign determination, provided that the phase lags are constant in time.

The phase correction values X, Y and Z respectively are tuned at the factory with the delivered coil frame and a search coil with a DC resistance = 4.8 Ohm. If required, the values may be adjusted by the system administrator. To determine the phase correction values, place the search coil approximately at the position within the coil frame which will be used later during your experiments. Align the orientation of the search coil to approximately 45° in the horizontal plane and 225° in the vertical plane. Thus, the vector angles should be –pi/2 for vector angle X, –pi/2 for vector angle Y and pi/2 for vector angle Z. Adjust the phase correction values X, Y and Z respectively to achieve the specified vector angles X, Y and Z. See also “5.4.9 Phase Correction X / Y / Z“ for further information.

The procedure described above to determine and set the phase correction values manually may be too laborious for the operator. Therefore it is strongly recommended to run automatic tuning to determine the optimal values. See ”5.6.4 Automatic Tuning of Phase Correction XYZ” for further details.

Notes:

- As mentioned above, the phase correction values X, Y and Z respectively are tuned at the factory. You should never change these settings manually if you are not sure what you are doing. Applying inappropriate settings may cause misleading output data, e.g. false sign of the vector lengths.
- Under no circumstances the phase correction should be disabled. Disabling the phase correction results in incorrect sign determination of the respective vector length X, Y and Z and therefore will cause corrupted output data. The phase correction is only temporarily disabled at the factory for testing purpose.

6.6 Using an optimal Gain of the Preamplifier

To achieve an optimal system performance, the level of the amplified search coil signal of a processed channel with a connected search coil must always be within a certain voltage range (operational range). This is achieved by setting the gain of the preamplifier to a reasonable value, depending on the characteristics of the connected search coil and the magnitude of the magnetic field. See “4.7 Search Coils“, “5.4.5 Preamplifier Gain” and “5.3.10 Field Signals Magnitude” for further details.

It may be too laborious for the operator to determine a reasonable value for the gain of the preamplifier manually. Therefore it is strongly recommended to run automatic tuning to determine an optimal value. See “5.6.1 Automatic Tuning of Preamplifier Gain” for further details.

Level Indicators

Whilst the menu system is deactivated, the display of the CS681 is filled with many information (see “5.1 Display Area”). Amongst others, the level indicators of the eight channels indicate the actual level of the amplified search coil signal of the respective channel. The range of the level indicator is from 0 to 100.

Indicated Level is below 32:
The level of the amplified search coil signal is too low, therefore the signal to noise ratio of this channel’s output data may be degraded. Increase the gain of the preamplifier for this channel and / or increase the magnitude of the magnetic field until the indicated level is in the range from 32 to 93.
Note: Too low levels are marked by brackets, e.g. >012<.

Indicated Level is in the range from 32 to 93:
If a channel is processed, the indicated level should always be in the range from 32 to 93, independently of the position and angular orientation of the connected search coil. This ensures a good signal to noise ratio of the channel’s output data and prevents overdriving of the system’s ADC due to the amplified search coil signal is within the operational range.

Indicated Level is above 93:
The level of the amplified search coil signal is too high, therefore the system’s ADC may be overdriven and the output data of this channel may be incorrect. It is essential to decrease the gain of the preamplifier for this channel and / or decrease the magnitude of the magnetic field until the indicated level is in the range from 32 to 93.
Note: Too high levels are marked by brackets, e.g. <100>.

6.7 Using the Low Pass Filter

The output data rate of the processed channels is 8 kHz, 4 kHz or 2 kHz, depending on the number of processed channels (see “5.3.2 Channels Processing” for further details). Should your application not need the full bandwidth of the respective output data rate, you may use a low pass filter to minimize noise on the output data. Depending on the particular requirements, the characteristics of the low pass filter may be selected by the operator (see “5.4.1 Low Pass Filter”).

If the low pass filter is used, the vector lengths X, Y and Z are low pass filtered before outputted and internally used for the trigonometric calculation of the angular data.

Each channel may have assigned different characteristics of the low pass filter. This allows the selective use of the low pass filter, e.g. if search coils with different characteristics are used concurrently.

Note:

You may use the test signals generated by the CS681 (see “5.3.1 System Mode”) and monitor the outputted vector lengths to get familiar with the different characteristics of the low pass filter. Consider that the vector lengths are low pass filtered. Therefore, when using the test signals, the effect of the low pass filter is only apparent on the outputted vector lengths.

7.0 Firmware Upgrade

This chapter describes the procedure to upgrade the firmware of the CS681.

The firmware of the CS681 is upgradeable by the system administrator. This allows the upgrade of the system on location if future versions of the firmware are available.

The firmware is uploaded to the CS681 with the delivered application software over the USB interface, i.e. a computer must be connected to the system's USB interface. The used computer should comply minimum requirements (see "4.9 External Computer"). The delivered application software (CS681Tools.exe) as well as the driver for the CS681 must be installed on the computer (see "4.9.1 Software Installation").

The firmware of the CS681 is split into four parts. Each part of the firmware may be separately uploaded to the CS681. Depending on the amount of a firmware upgrade, only certain parts or all four parts must be uploaded to complete the upgrade. The delivered application software gives information concerning the currently used code revision of the firmware on the tab "Generic" of the system settings.

The new firmware comes packed in a ZIP file, containing the firmware files of the parts, which are affected by the upgrade, and a text file with additional information concerning the new firmware.

The table below lists the four parts of the firmware and the extension of the associated firmware files:

Firmware Part	Firmware File Extension
DSP Code	.dsp
FPGA Bitstream	.fpg
Display Board Code	.dis
Preamplifier Code	.pre

Caution:

- Once started, the firmware upload can not be stopped until it is completed
- If the firmware upload can not be completed successfully, the system may become inoperable
- If an inappropriate firmware file is uploaded, the system becomes inoperable

Follow these steps to upgrade the firmware of the CS681. Note that the screenshots in the table depict the upload of a DSP Code file.

Step 1

Unzip the file with the new firmware and carefully read the unzipped file “readme.txt” for additional instructions.

Step 2

Connect a computer to the USB interface of the CS681.The delivered application software (CS681Tools.exe) and the driver for the CS681 must already be installed on the used computer. The unzipped firmware files must be accessible by the used computer.

Step 3

Turn the power of the CS681 on.

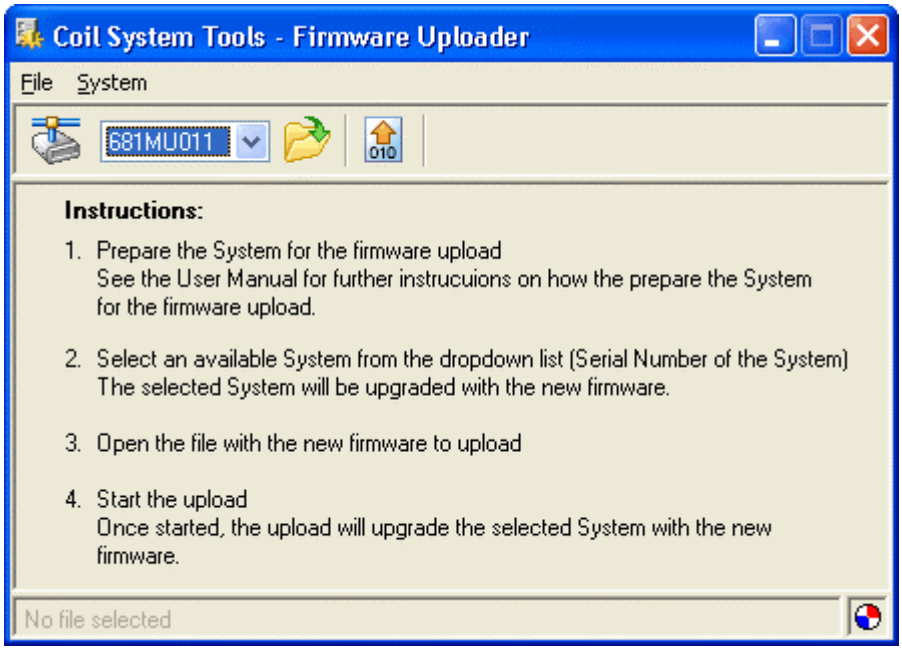
Step 4

Start the application software (CS681Tools.exe) and open the ‘Firmware Uploader’ (“Options > Firmware Upload…”).

Note that the access to the ‘Firmware Uploader’ is protected with a password. Enter the password and click “OK” to continue:

Step 5

After the password was entered, the 'Firmware Uploader' is ready:



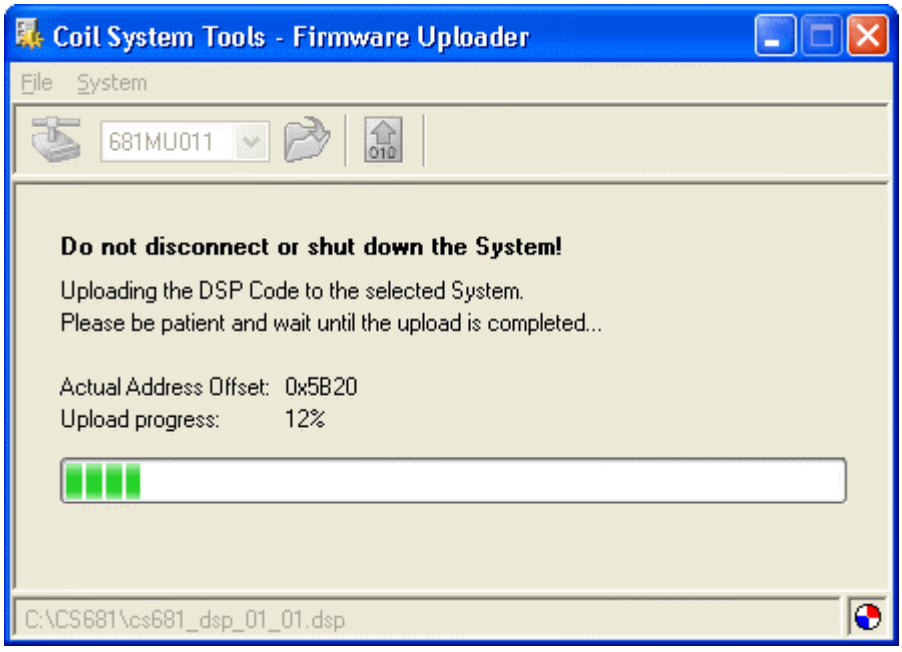
Select an available System from the dropdown list (Serial Number of the System). The selected System will be upgraded with the new firmware.

Select the firmware file to be uploaded ("File > Open…"). If the amount of the firmware upgrade includes several firmware files, it is very important to observe the sequence of the uploaded files! See the instructions in the unzipped file "readme.txt" for further details.

Once you are ready, start the upload ("System > Start Firmware Upload…"). Check again your selections and click "Yes" in the following message box:

Step 6

The ‘Firmware Uploader’ transmits the firmware file to the selected CS681:



Caution:

Do not disconnect or shut down the CS681 while the firmware upload is in progress! If the firmware upload can not be completed successfully, the system may become inoperable!

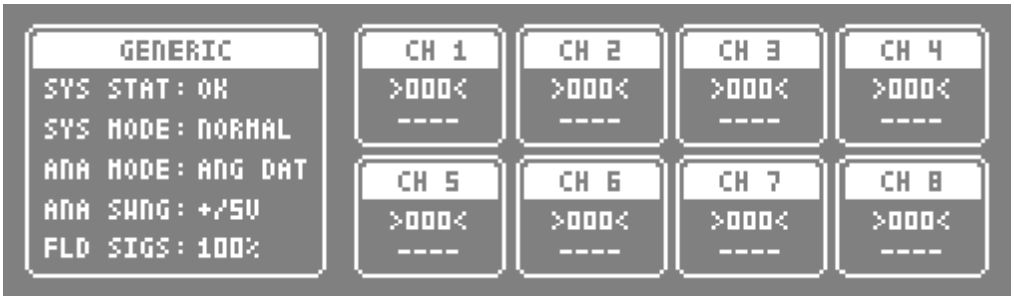
Wait until the firmware upload is completed…

Step 7

Finally, the ‘Firmware Uploader’ should display a message indicating that the upload was successful. Click "OK" to exit the ‘Firmware Uploader’:

Step 8

Turn the power of the CS681 off, wait approx. 10 seconds and turn the power of the CS681 on. The system starts with the upgraded firmware:



Note that the figure above is an example. Depending on the uploaded firmware and the actual setup, the appearance of the display may be different.

Depending on the amount of the firmware upgrade, it may now be required to upload another firmware file. Read the unzipped file “readme.txt” for further instructions.

8.0 Specifications

Main Unit	
Recording Channels	8 channels
Recording Range	360° in the horizontal plane ± 80° in the vertical plane
Output Data Rate	Depending on the number of processed channels, user selectable: - 8000 Hz (2 channels processed) - 4000 Hz (4 channels processed) - 2000 Hz (8 channels processed)
Resolution	< 0.0002°
Noise	Full bandwidth: < 0.0028° RMS, < 0.018° peak-peak (search coil at 180° hor, 0° vert) < 0.0035° RMS, < 0.024° peak-peak (search coil at 180° hor, 40° vert) 200 Hz Bandwidth (internal low pass filter, 200 Hz Bessel 4th order): < 0.0015° RMS, < 0.008° peak-peak (search coil at 180° hor, 0° vert) < 0.0018° RMS, < 0.010° peak-peak (search coil at 180° hor, 40° vert)
Drift	< 0.1° within 30 minutes after power-on (warm-up), negligible after warm-up
Linearity	Horizontal < 0.4° deviation within 360° Vertical < 0.3° deviation between ±70°
Low Pass Filter	Digital low pass filter with user selectable characteristics per channel: - Disabled - Bessel or Butterworth, IIR, 4th order, 500 Hz, 200 Hz or 50 Hz - Moving average (FIR) with 8, 16 or 32 taps
Front Panel	Field Signals: - Frequencies: 105.79 kHz, 113.93 kHz, 122.07 kHz (X, Y, Z-Axis, note 1) - Nominal Output Voltage: Depends on the used coil frame (note 2) Preamplifier Interface: - Power supply and data interface to the external preamplifier Analog Outputs: - 24 analog outputs, user selectable data format - Voltage Swing: ±2 V, ±2.5 V, ±4 V, ±4.5 V or ±5 V (user selectable) - Resolution: 14 Bit - Output Impedance: 200 Ohm typical USB Interface: - USB 1.1 / 2.0 interface, bulk data transfer - Resolution of the transmitted output data: 21 Bit Mains Power Switch: - System power on / off Display with Touch Screen: - User adjustable contrast and backlight intensity - Menu system to control the system configuration
Rear Panel	Mains Power Input: - 230 VAC ± 10 %, 50 Hz / 115 VAC ± 10 %, 60 Hz (250 VA max.)
Outline Dimension	255 x 110 x 310 mm (w x h x d)
Weight	6.5 kg

Preamplifier	
Recording Channels	8 channels, user adjustable gain setting per channel
Input Impedance	600 Ohm typical (100 kHz)
Supply Voltage	±5 VDC, ±300 mA max. (power supply is provided by the main unit)
Outline Dimensions	76 x 35 x 154 mm (w x h x d)
Weight	420 g
Coil Frame	
In General	Three coils with two turns each, arranged as a cube Optional version “Removable Bars” available, which allows the straightforward opening of the coil frame, e.g. to insert a primate chair
Magnetic Flux Density	15 uT typical (note 3)
Coil Material	Anodized aluminum bars, cross section 8 mm
Coil Color	Various colors available, contact Primelec for further information
Dimension	Dimension L1 may be specified by the customer in the range from 250 to 700 mm, see drawing below
Weight	Depends on the coil dimensions, for example approx. 5 kg for L1 = 700 mm (including Matching-Box)
Search Coils	
Material	Preferably double insulated copper wire, Ø 20um
DC-Resistance	100 Ohm max. (note 4)
Effective Area	0.5 cm² ... 100 cm² (note 5)
Weight	Depends on material, dimensions and manufacturing process, for example approx. 2 mg for a double insulated copper coil with a diameter of 2 mm and 80 turns

Note 1: Other frequencies for the field signals on request, contact Primelec for further information.

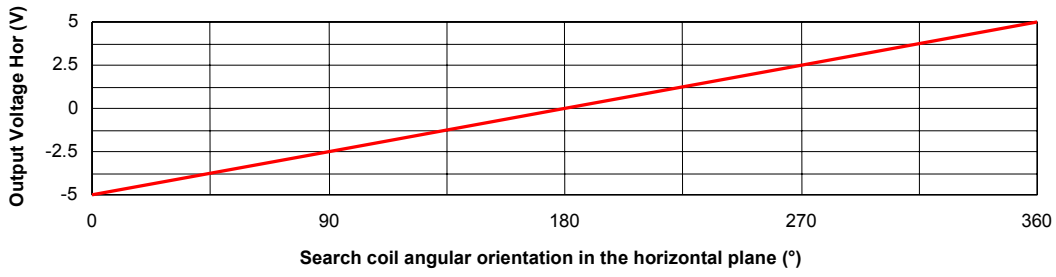
Note 2: The nominal output voltage of each field signal is tuned at the factory to achieve the specified magnetic flux density and an optimal field homogeneity at the 3D-centre of the coil frame. The tuned field signals may be attenuated by the operator in steps of 10 % down to zero.
The maximum output voltage of each field signal is 18.4 V_{RMS} differential measured.

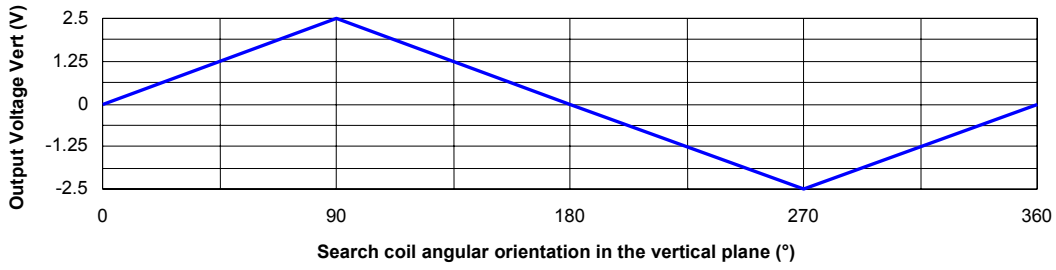
Note 3: The specified magnetic flux density refers to the nominal output voltage of the field signals. The magnetic flux density may be reduced by the operator in steps of 10 % down to zero.

Note 4: The DC resistance should not be higher than specified to achieve the specified noise of the system’s output data. Higher DC resistance may increase the noise of the system’s output data.

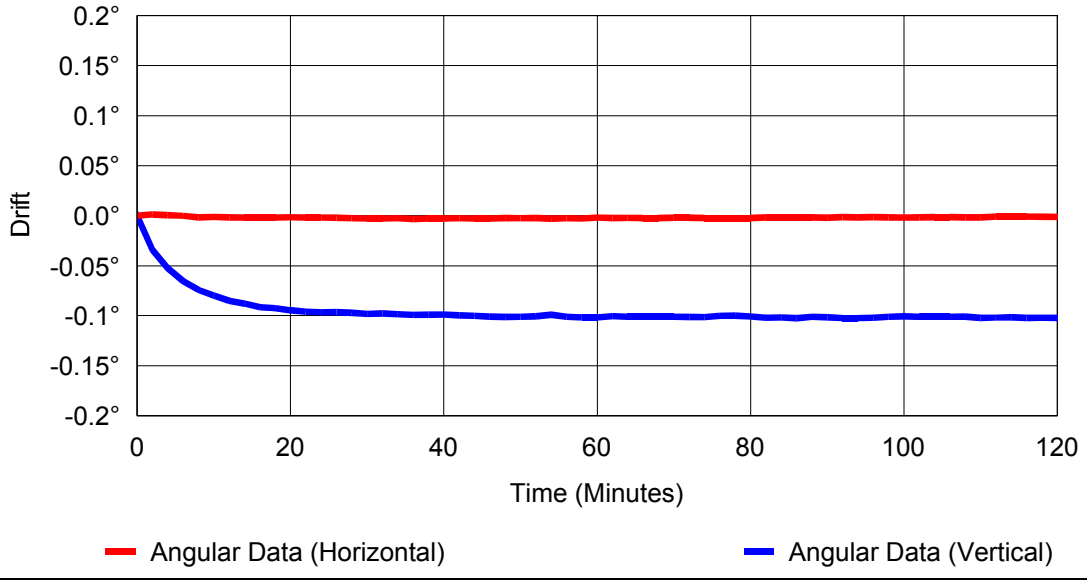
Note 5: Effective Area = n D² pi / 4 (where n is the number of turns and D is the diameter)
Smaller effective area may be used, possibly resulting in increased noise of the system’s output data. Larger effective area (up to 1000 cm²) may be used by reducing the magnetic flux density.

Typical progression of the analog output signals (note 6)

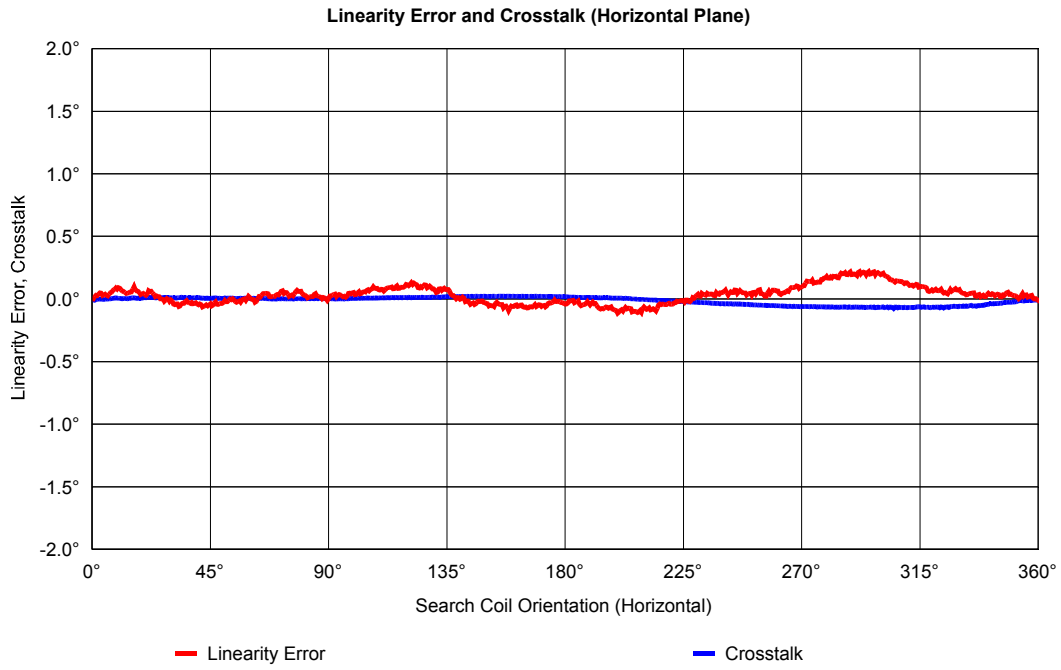


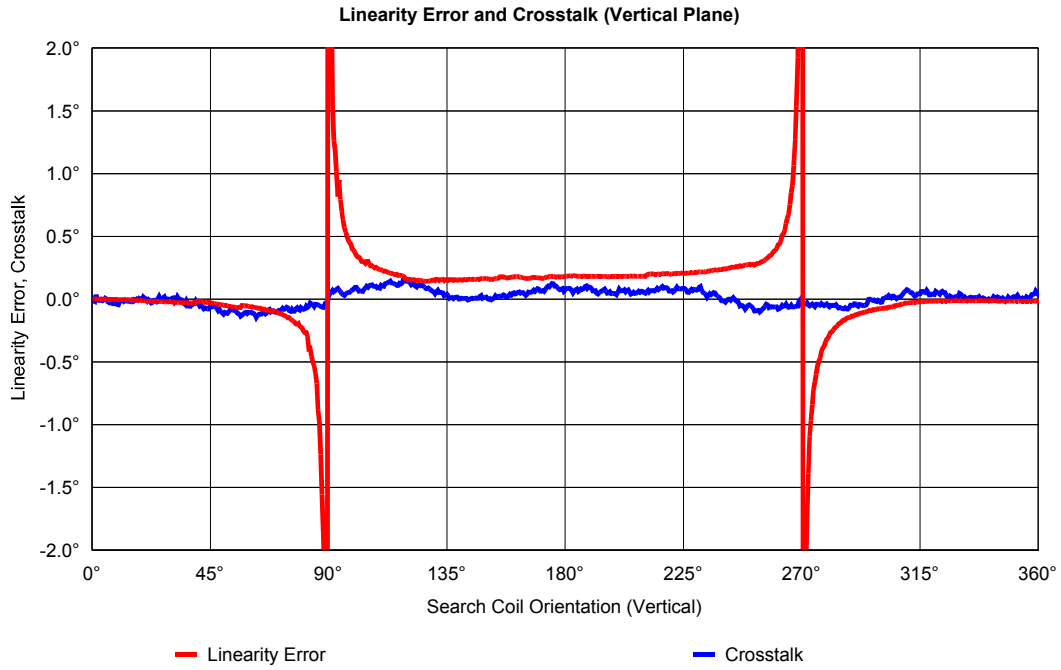


Warm-Up Drift (note 7)



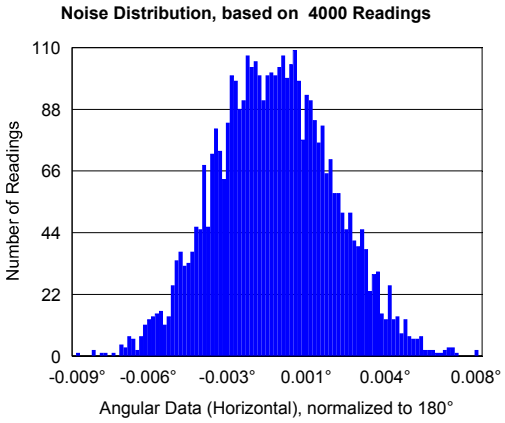
Linearity Error and Crosstalk (note 7)

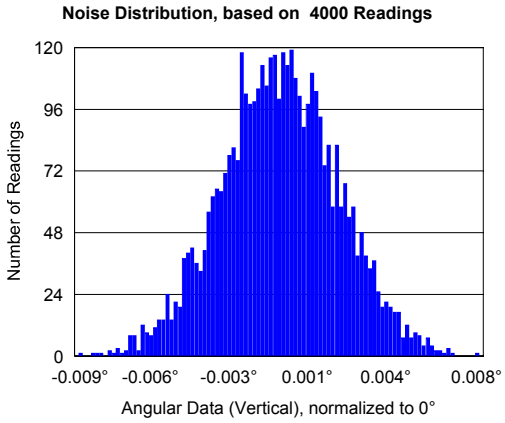




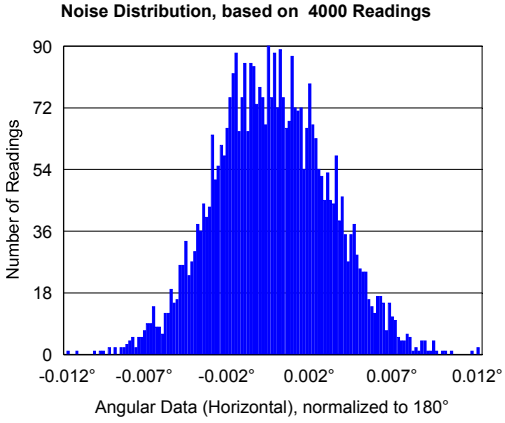
Distribution of Angular Noise (note 7)

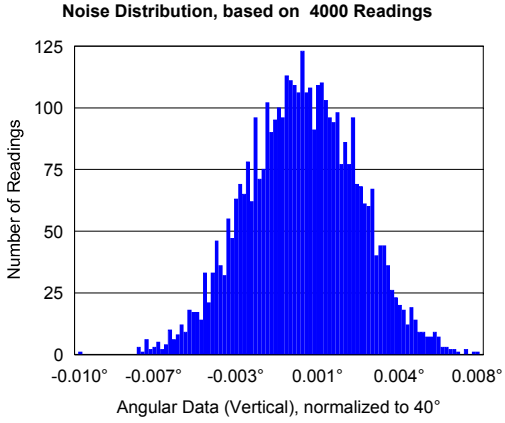
Search Coil Orientation: Horizontal 180°, Vertical 0°



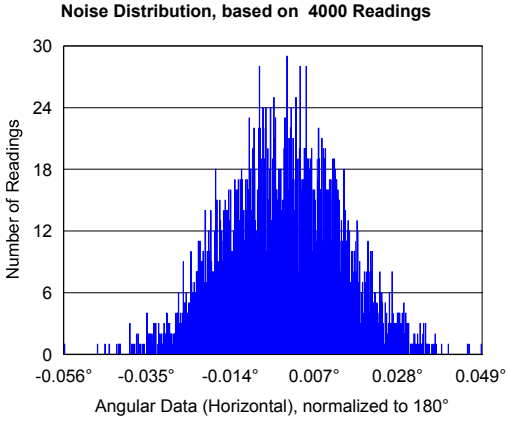


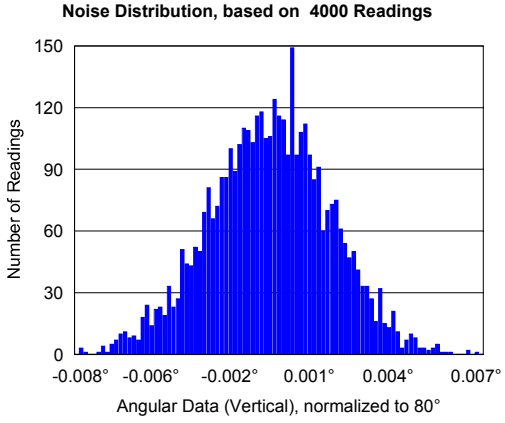
Search Coil Orientation: Horizontal 180°, Vertical 40°





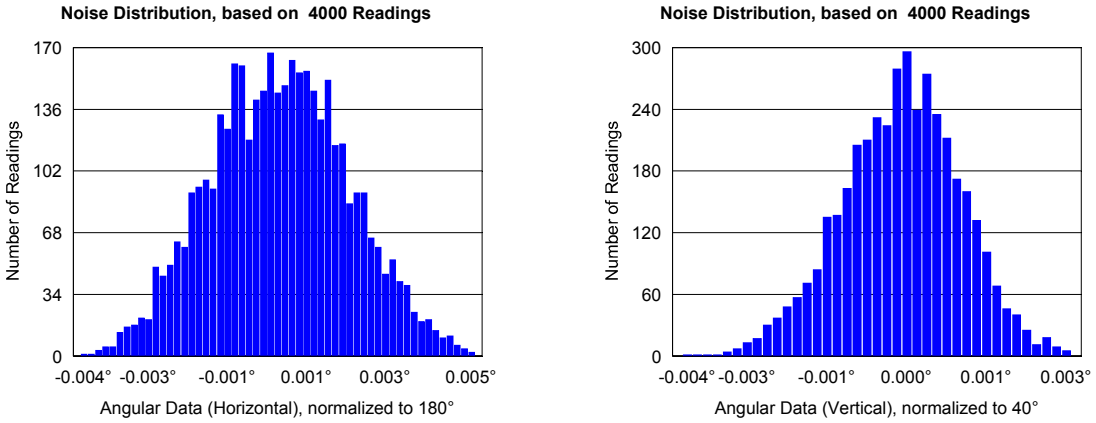
Search Coil Orientation: Horizontal 180°, Vertical 80°



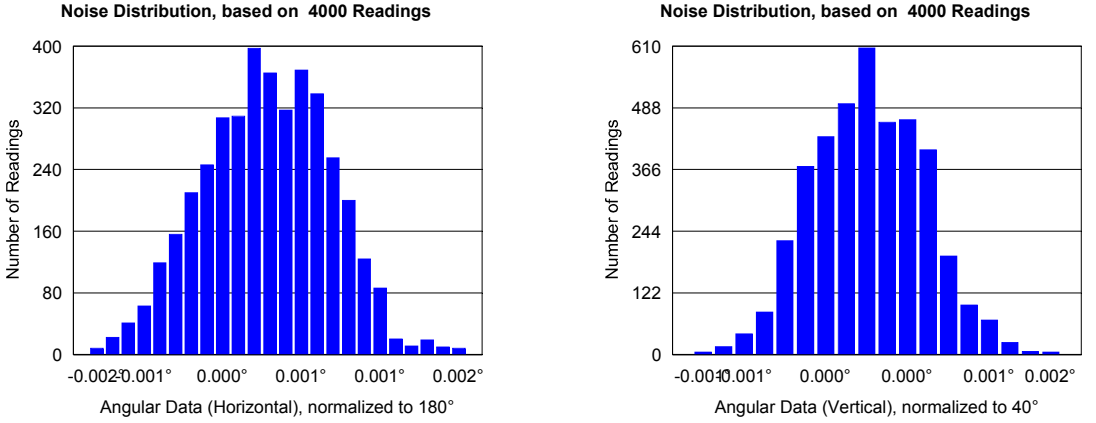


Distribution of Angular Noise (note 8, note 9)

Search Coil Orientation: Horizontal 180°, Vertical 40° (note 8)



Search Coil Orientation: Horizontal 180°, Vertical 40° (note 9)



Note 6: Output Mode: Angular Data, Output Swing: ±5 Volt

Note 7: Used setup for the performance measurements:
- Coil frame L1 = 700 mm
- Search coil effective area = 10.8 cm^2, R_{DC} = 4.8 Ohm
- Angular data acquired over the USB interface
- 8 channels processed
- Gain correction disabled
- Offset correction disabled
- Field signals magnitude 100 %
- Preamplifier gain setting = 17
- Low pass filter disabled (unless otherwise noted)

Note 8: Used setup as described in note 7, except for:
- Low pass filter enabled, characteristics: Bessel, 200 Hz, 4^{th} order, IIR

Note 9: Used setup as described in note 7, except for:
- Low pass filter enabled, characteristics: Bessel, 50 Hz, 4^{th} order, IIR

9.0 Appendix

9.1 Pin Numbering and Signal Assignments

9.1.1 Main Unit

'Field Signals', 25 contacts socket connector D-SUB

Pin	Signal
1	Field Signal Z1+ output
2	Field Signal Z1– output
3	Field Signal Z2+ output (reserved for future use, do not connect)
4	Field Signal Z2– output (reserved for future use, do not connect)
5	Field Signal Y1+ output
6	Field Signal Y1– output
7	Field Signal Y2+ output (reserved for future use, do not connect)
8	Field Signal Y2– output (reserved for future use, do not connect)
9	Field Signal X1+ output
10	Field Signal X1– output
11	Field Signal X2+ output (reserved for future use, do not connect)
12	Field Signal X2– output (reserved for future use, do not connect)
13	+12V (max. 100 mA, DC power for the version "Removable Bars")
14	GND
15	GND
16	GND
17	GND
18	GND
19	GND
20	GND
21	GND
22	GND
23	GND
24	GND
25	GND

‘Preamplifier’, 15 contacts socket connector D-SUB

Pin	Signal
1	VIM_ODD, odd channels multiplexed input –
2	GND
3	VIM_EVEN, even channels multiplexed input –
4	GND
5	MUX_A0, multiplexers address 0 output
6	5VM, -5V power output
7	SDA, control interface I2C SDA input / output
8	5VP, +5V power output
9	VIP_ODD, odd channels multiplexed input +
10	GND
11	VIP_EVEN, even channels multiplexed input +
12	GND
13	MUX_A1, multiplexers address 1 output
14	GND
15	SCL, control interface I2C SCL output

'Analog Outputs', 25 contacts pin connector D-SUB

Pin	Signal, depending on Analog Outputs Mode:		
	Angular Data	Vector Length	Vector Angle
1	GND	GND	GND
2	Channel 1, A (Hor)	Channel 1, X	Channel 1, X
3	Channel 1, B (Vert)	Channel 1, Y	Channel 1, Y
4	No signal (0 V)	Channel 1, Z	Channel 1, Z
5	Channel 2, A (Hor)	Channel 2, X	Channel 2, X
6	Channel 2, B (Vert)	Channel 2, Y	Channel 2, Y
7	No signal (0 V)	Channel 2, Z	Channel 2, Z
8	Channel 3, A (Hor)	Channel 3, X	Channel 3, X
9	Channel 3, B (Vert)	Channel 3, Y	Channel 3, Y
10	No signal (0 V)	Channel 3, Z	Channel 3, Z
11	Channel 4, A (Hor)	Channel 4, X	Channel 4, X
12	Channel 4, B (Vert)	Channel 4, Y	Channel 4, Y
13	No signal (0 V)	Channel 4, Z	Channel 4, Z
14	Channel 5, A (Hor)	Channel 5, X	Channel 5, X
15	Channel 5, B (Vert)	Channel 5, Y	Channel 5, Y
16	No signal (0 V)	Channel 5, Z	Channel 5, Z
17	Channel 6, A (Hor)	Channel 6, X	Channel 6, X
18	Channel 6, B (Vert)	Channel 6, Y	Channel 6, Y
19	No signal (0 V)	Channel 6, Z	Channel 6, Z
20	Channel 7, A (Hor)	Channel 7, X	Channel 7, X
21	Channel 7, B (Vert)	Channel 7, Y	Channel 7, Y
22	No signal (0 V)	Channel 7, Z	Channel 7, Z
23	Channel 8, A (Hor)	Channel 8, X	Channel 8, X
24	Channel 8, B (Vert)	Channel 8, Y	Channel 8, Y
25	No signal (0 V)	Channel 8, Z	Channel 8, Z

'USB', USB Type B connector

Pin	Signal
1	VCC
2	Data –
3	Data +
4	GND

9.1.2 Coil Frame (Matching-Box)

'Field Signals', 15 contacts pin connector D-SUB

Pin	Signal
1	Field Signal X + input
2	Field Signal X – input
3	Field Signal Y + input
4	Field Signal Y – input
5	Field Signal Z + input
6	Field Signal Z – input
7	No internal connection (not used)
8	VDC-, 0 V auxiliary supply voltage input (1)
9	No internal connection (not used)
10	No internal connection (not used)
11	No internal connection (not used)
12	No internal connection (not used)
13	No internal connection (not used)
14	No internal connection (not used)
15	VDC+, +12 V auxiliary supply voltage input (1)

(1) The auxiliary supply voltage is only required in conjunction with the optional version "Coil Frame with Removable Bars"

9.1.3 Preamplifier

'Preamplifier', 15 contacts socket connector D-SUB

Pin	Signal
1	VOM_ODD, odd channels multiplexed output –
2	GND
3	VOM_EVEN, even channels multiplexed output –
4	GND
5	MUX_A0, multiplexers address 0 input
6	5VM, -5V power input
7	SDA, control interface I2C SDA input / output
8	5VP, +5V power input
9	VOP_ODD, odd channels multiplexed output +
10	GND
11	VOP_EVEN, even channels multiplexed output +
12	GND
13	MUX_A1, multiplexers address 1 input
14	GND
15	SCL, control interface I2C SCL input

‘Search Coils (even Channels)’, 9 contacts socket connector MICRO-T

Pin	Signal
1	Channel 6, Search Coil input –
2	Channel 6, Search Coil input +
3	GND
4	Channel 4, Search Coil input –
5	Channel 4, Search Coil input +
6	Channel 8, Search Coil input +
7	Channel 8, Search Coil input –
8	Channel 2, Search Coil input +
9	Channel 2, Search Coil input –

‘Search Coils (odd Channels)’, 9 contacts socket connector MICRO-T

Pin	Signal
1	Channel 5, Search Coil input –
2	Channel 5, Search Coil input +
3	GND
4	Channel 3, Search Coil input –
5	Channel 3, Search Coil input +
6	Channel 7, Search Coil input +
7	Channel 7, Search Coil input –
8	Channel 1, Search Coil input +
9	Channel 1, Search Coil input –

9.2 Slip Ring Wiring

Sig#	Signal Name	Connector	Cabling	TP	SD	Slip Ring Contact
1	Field Signal X1+	'Field Signals', pin 9	AWG 22	1a	1	50 V / 500 mA
2	Field Signal X1–	'Field Signals', pin 10	AWG 22	1b	1	50 V / 500 mA
3	GND	'Field Signals', pin 22	Shield		1	5 V / 25 mA
4	Field Signal Y1+	'Field Signals', pin 5	AWG 22	2a	2	50 V / 500 mA
5	Field Signal Y1–	'Field Signals', pin 6	AWG 22	2b	2	50 V / 500 mA
6	GND	'Field Signals', pin 18	Shield		2	5 V / 25 mA
7	Field Signal Z1+	'Field Signals', pin 1	AWG 22	3a	3	50 V / 500 mA
8	Field Signal Z1–	'Field Signals', pin 2	AWG 22	3b	3	50 V / 500 mA
9	GND	'Field Signals', pin 14	Shield		3	5 V / 25 mA
10	VOM_ODD	'Preamplifier', pin 1	AWG 26	4a	4	5 V / 25 mA
11	VOP_ODD	'Preamplifier', pin 9	AWG 26	4b	4	5 V / 25 mA
12	GND	'Preamplifier', pin 10	Shield		4	5 V / 25 mA
13	VOM_EVEN	'Preamplifier', pin 3	AWG 26	5a	5	5 V / 25 mA
14	VOP_EVEN	'Preamplifier', pin 11	AWG 26	5b	5	5 V / 25 mA
15	GND	'Preamplifier', pin 10	Shield		5	5 V / 25 mA
16	SCL	'Preamplifier', pin 15	AWG 26	6a	6	5 V / 25 mA
17	GND	'Preamplifier', pin 14	AWG 26	6b	6	5 V / 25 mA
18	SDA	'Preamplifier', pin 7	AWG 26	7a	6	5 V / 25 mA
19	GND	'Preamplifier', pin 4	AWG 26	7b	6	5 V / 25 mA
20	MUX_A0	'Preamplifier', pin 5	AWG 26	8a	6	5 V / 25 mA
21	GND	'Preamplifier', pin 2	AWG 26	8b	6	5 V / 25 mA
22	MUX_A1	'Preamplifier', pin 13	AWG 26	9a	6	5 V / 25 mA
23	GND	'Preamplifier', pin 12	AWG 26	9b	6	5 V / 25 mA
24	5VP	'Preamplifier', pin 8	AWG 22	10a	6	5 V / 500 mA
25	5VM	'Preamplifier', pin 6	AWG 22	10b	6	5 V / 500 mA
26	GND	'Preamplifier', pin 10	Shield		6	5 V / 500 mA

TP means Twisted Pair, SD means Shield

Two additional slip ring contacts (12 V / 100 mA) are required in conjunction with the optional version "Coil Frame with Removable Bars" for the DC power signals GND and +12V

Use one slip ring contact per ground connection as listed in the table above. If not possible:

- Signals #3, #6 and #9 (GND) may share one slip ring contact (5 V / 25 mA)
- Signals #12 and #15 (GND) may share one slip ring contact (5 V / 25 mA)
- Signals #17, #19, #21 and #23 (GND) may share one slip ring contact (5 V / 25 mA)

Allocate and wire the slip ring contacts such that crosstalk between the field signals and from the field signals to the outputs of the preamplifier (signals #10, #11, #13 and #14) is prevented.

9.3 Test Modes

Note:

The specified timing of the test signals generated in the Test Modes 4 to 9 depends on the number of processed channels, i.e. CH 1 to CH 2, CH 1 to CH 4 or CH 1 to CH 8.

Test 1 (Min)

Waveform: DC

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data	0	90	-250000	-250000	-250000	-3.1415	-3.1415	-3.1415

Test 2 (Mid)

Waveform: DC

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data	180	180	0	0	0	0	0	0

Test 3 (Max)

Waveform: DC

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data	359.999	270	250000	250000	250000	3.1415	3.1415	3.1415

Test 4 (Rect #1)

Waveform: Rectangular

Timing: 250 us / period, 500 us / period, 1000 us / period

Resolution: 2 levels / period

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data min	0	90	-250000	-250000	-250000	-3.1415	-3.1415	-3.1415
Data max	359.999	270	250000	250000	250000	3.1415	3.1415	3.1415

Test 5 (Rect # 2)

Waveform: Rectangular

Timing: 8 ms / period, 16 ms / period, 32 ms / period

Resolution: 2 levels / period

	Ang A [1]	Ang B [1]	VL X [2]	VL Y [2]	VL Z [2]	VA X [3]	VA Y [3]	VA Z [3]
Data min	0	90	-250000	-250000	-250000	-3.1415	-3.1415	-3.1415
Data max	359.999	270	250000	250000	250000	3.1415	3.1415	3.1415

[1] Timing offset Ang A → Ang B 0% → 50%
[2] Timing offset VL X → VL_Y → VL_Z 0% → 25 % → 50%
[3] Timing offset VA X → VA_Y → VA_Z 0% → 25 % → 50%

Test 6 (Rect #3)

Waveform: Rectangular

Timing: 2.048 s / period, 4.096 s / period, 8.192 s / period

Resolution: 2 levels / period

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data min	0	90	-250000	-250000	-250000	-3.1415	-3.1415	-3.1415
Data max	359.999	270	250000	250000	250000	3.1415	3.1415	3.1415

Test 7 (Ramp #1)

Waveform: Sawtooth

Timing: 8 ms / period, 16 ms / period, 32 ms / period

Resolution: 64 levels / period

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data min	0	90	90000	-80000	-250000	1.1308	-1.0050	-3.1415
Data max	359.999	270	250000	80000	-90000	3.1415	1.0050	-1.1308

Test 8 (Ramp #2)

Waveform: Sawtooth

Timing: 128 ms / period, 256 ms / period, 512 ms / period

Resolution: 1024 levels / period

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data min	0	90	-250000	-250000	-250000	-3.1415	-3.1415	-3.1415
Data max	359.999	270	250000	250000	250000	3.1415	3.1415	3.1415

Test 9 (Ramp #3)

Waveform: Sawtooth

Timing: 2.048 s / period, 4.096 s / period, 8.192 s / period

Resolution: 16384 levels / period

	Ang A	Ang B	VL X	VL Y	VL Z	VA X	VA Y	VA Z
Data min	0	90	-250000	-250000	-250000	-3.1415	-3.1415	-3.1415
Data max	359.999	270	250000	250000	250000	3.1415	3.1415	3.1415

9.4 System Status

System Status Bits description (combinations possible)

Value	Description
1	Main Board EEPROM Data Memory Error Main unit internal error. Contact factory for further instructions.
2	Main Board Reference-DAC Error Main unit internal error. Contact factory for further instructions.
4	Main Board Temperature Sensor Error Main unit internal error. Contact factory for further instructions.
8	Main Board Temperature Alarm The maximum tolerable temperature (60°C) inside of the cabinet of the main unit is exceeded. Contact factory for further instructions.
16	Main Board Power Failure Main unit internal error. One or several internal supply voltages of the main unit are missing. Contact factory for further instructions.
32	Reserved for future use; currently not used (always 0)
64	Reserved for future use; currently not used (always 0)
128	Display Board Communication Error Main unit internal error. Contact factory for further instructions.
256	Preamplifier Communication Error Preamplifier not connected or preamplifier defective or main unit internal error. If the preamplifier is not connected to the main unit, it is normal to get this error. If the preamplifier is connected to the main unit and the error still appears after system power off / on, contact factory for further instructions.

9.5 Preamplifier Status

Preamplifier Status Bits description (combinations possible)

Value	Description
1	EEPROM Data Memory Communication Timeout Communication error or preamplifier internal error. Contact factory for further instructions.
2	EEPROM Data Memory Verify Error Communication error or preamplifier internal error. Contact factory for further instructions.
4	Invalid Rx-Packet Communication error or preamplifier internal error. Contact factory for further instructions.
8	Invalid Tx-Packet Communication error or preamplifier internal error. Contact factory for further instructions.
16	Invalid Packet Content Communication error or preamplifier internal error. Contact factory for further instructions.
32	Status Reading Failure If this bit is set, the remaining preamplifier status bits are not valid, i.e. all reset to zero. Preamplifier not connected or preamplifier defective or main unit internal error If the preamplifier is not connected to the main unit, it is normal to get this failure. If the preamplifier is connected to the main unit and the error still appears after system power off / on, contact factory for further instructions.

10.0 Personal Notes