

CS681 – Magnetic Search Coil System

- **Primelec is an independent Swiss company which was founded in 1986 by Daniel Florin**
- **Primelec has more than 20 years of experience in the field of search coil systems (first system introduced in 1989)**
- **The CS681 is the third generation of Primelec's search coil systems, introduced in 2006**
- **Intended for the recording of 3D eye and head movements**
- **Probably the most advanced search coil system on the market**
- **In use at universities and research institutions throughout the world**
- **Engineering, assembly, testing, sales and support by Primelec, module fabrication by external Swiss manufacturers (ISO certified)**

Main Features

- **8 recording channels**
- **Digital processing of up to 8 search coils in real-time**
- **Linear angular output data (horizontal and vertical)**
- **Raw output data (detected signals X, Y and Z)**
- **Digital interface (USB 1.1 / 2.0)**
- **Analog interfaces (24 analog outputs)**
- **Digital gain- and offset correction per channel (optional use)**
- **Customizable digital lowpass filter per channel (optional use)**
- **Application software and ActiveX control included (Windows 2000 / XP)**

User Friendly

- **Easy to use**
- **Menu controlled operation (LCD with touch screen)**
- **Straightforward system configuration**
- **Automatic tuning of the gain- and offset settings**
- **Nonvolatile memory for 10 user specific system configurations**
- **Software examples included (VB source code, LabVIEW VI)**
- **Detailed user manual included**
- **Comprehensive customer support by Primelec**
- **Two years full warranty**



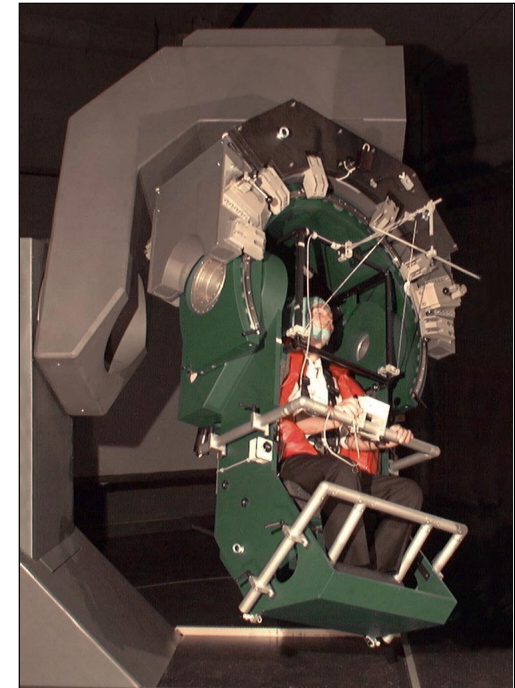
High Performance

- **Output data rate 8 kHz (2 channels processed, 2 kHz with 8 channels)**
- **Resolution $< 0.0002^\circ$**
- **Noise $< 0.0028^\circ$ RMS (full bandwidth)**
- **Drift $< 0.1^\circ$ within 30 minutes warm-up time after power-on, negligible drift after warm-up**
- **Horizontal detection range 360°**
- **Horizontal deviation $< 0.4^\circ$ within 360° detection range**
- **Vertical detection range $\pm 70^\circ$**
- **Vertical deviation $< 0.3^\circ$ within $\pm 70^\circ$ detection range**



Main Applications

- Recording of 3D eye and head movements of unrestrained laboratory animals
- Neurophysiological, ophthalmological, psychological, psychiatric and visual studies
- Recording of saccades, vergence, smooth pursuit, vestibular and optokinetic eye movements and miniature eye movements such as drift, tremor and microsaccades
- For research use only; no certifications or approvals for clinical purposes
- All use of the system must be in compliance with appropriate standards and procedures



Multi-axes turntable, equipped with Primelec search coil system
(by courtesy of Prof. D. Straumann, Neurology Department of the University Hospital Zurich)



Measuring Principle

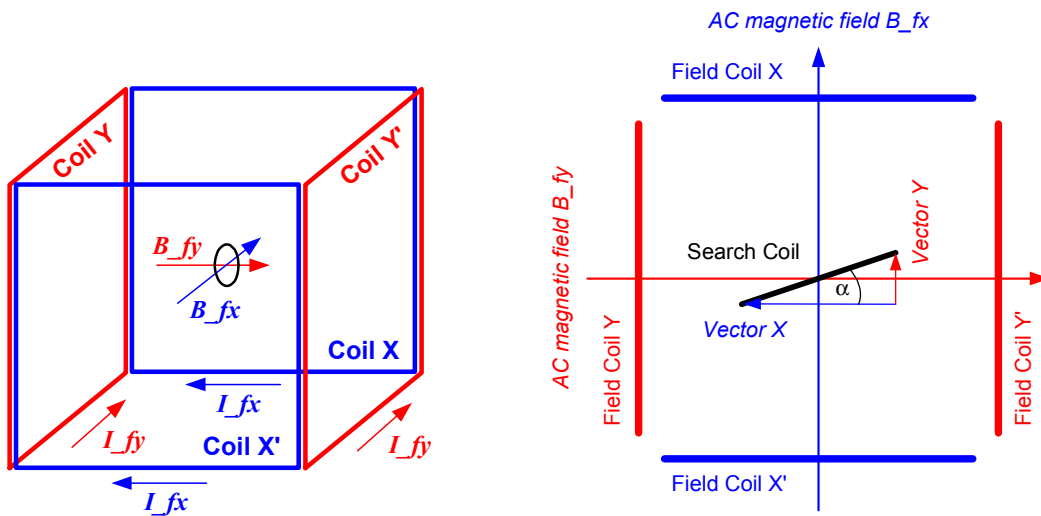
- **Based on the magnetic field search coil technique introduced in 1963 by D. A. Robinson**
- **Three magnetic fields with different frequencies, arranged in space quadrature (digitally synthesized field signals)**
- **Integrated analog to digital converters digitize the search coil signals**
- **Phase-locked amplitude detection based on the FFT of the digitized search coil signals, technique introduced in 1999 by Primelec**
- **Computation of the FFT and the subsequent trigonometric calculations in real-time by the integrated DSP**
- **Digital output data over the integrated USB-Interface and analog data output over the integrated digital to analog converters**



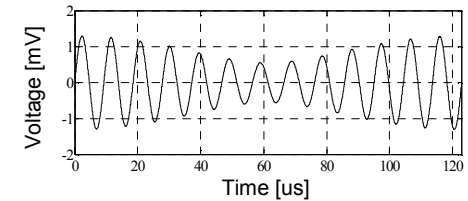
Measuring Principle – Time and Frequency Domain

Schematical diagram of a search coil, placed in a AC magnetic field generated by the field coils X-X' (current I_{fx}) and Y-Y' (current I_{fy}). For simplicity, only a two-dimensional coil frame is shown.

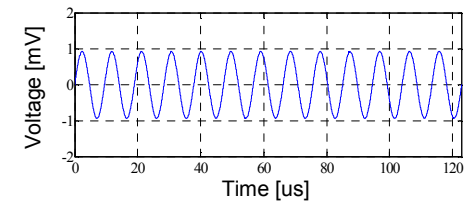
The spectral components of the two field frequencies f_x and f_y in the resulting search coil signal are proportional to the sine of the angular displacement of the search coil relative to the coil frame (angle α).



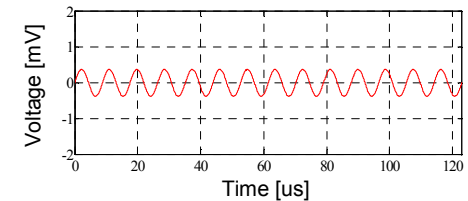
Search coil signal (time domain)



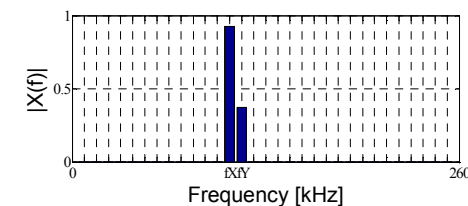
Fraction of f_x (time domain)



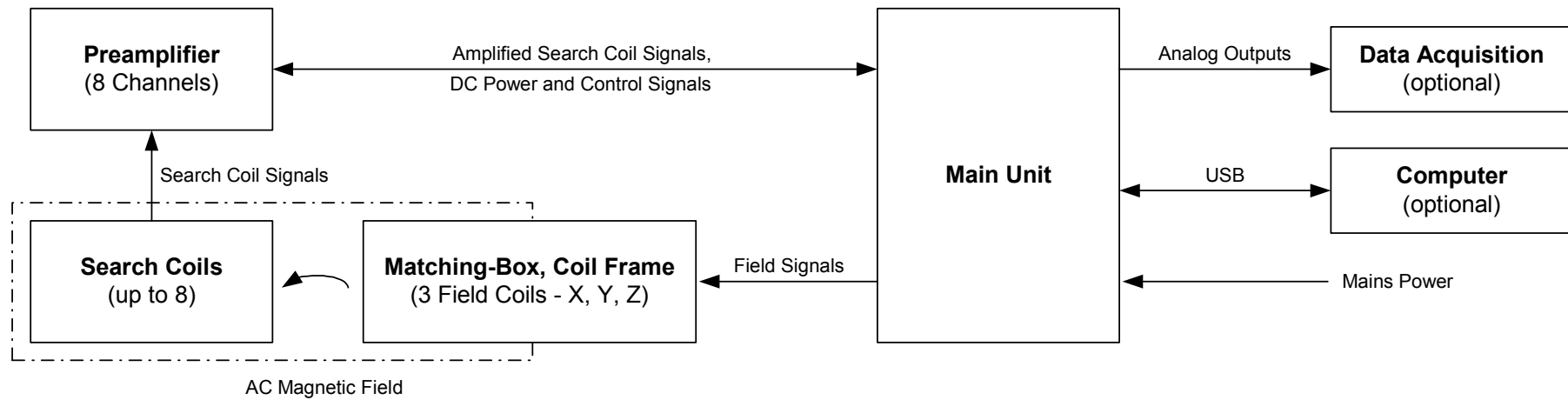
Fraction of f_y (time domain)



Search coil signal (frequency domain)



System Overview



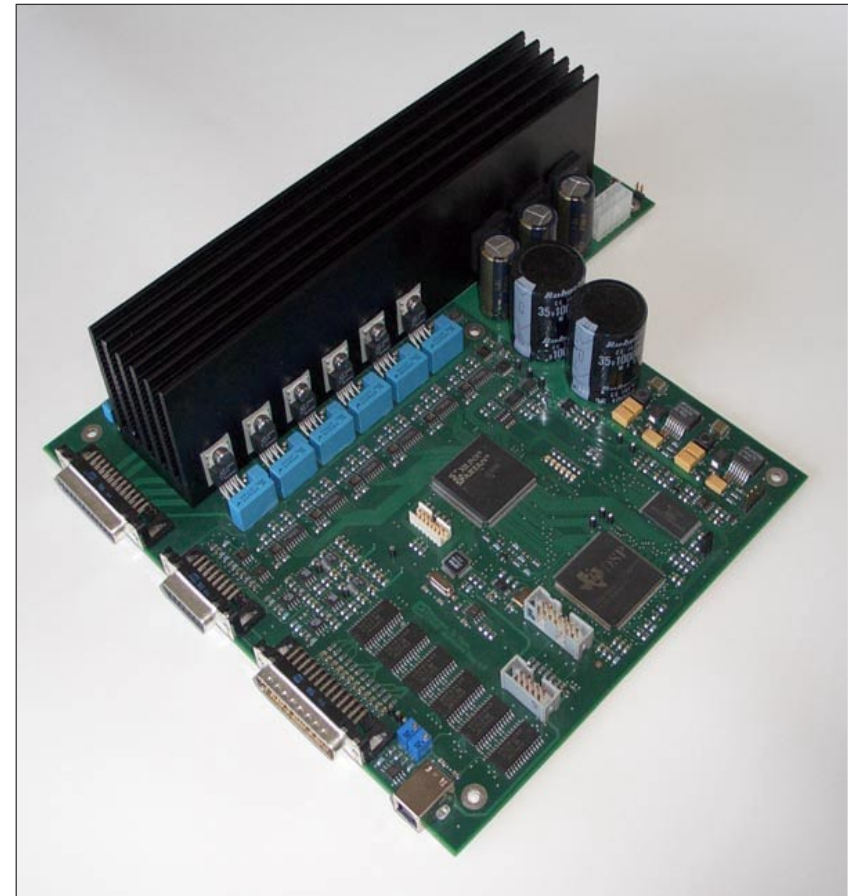
Main Unit



Main Unit

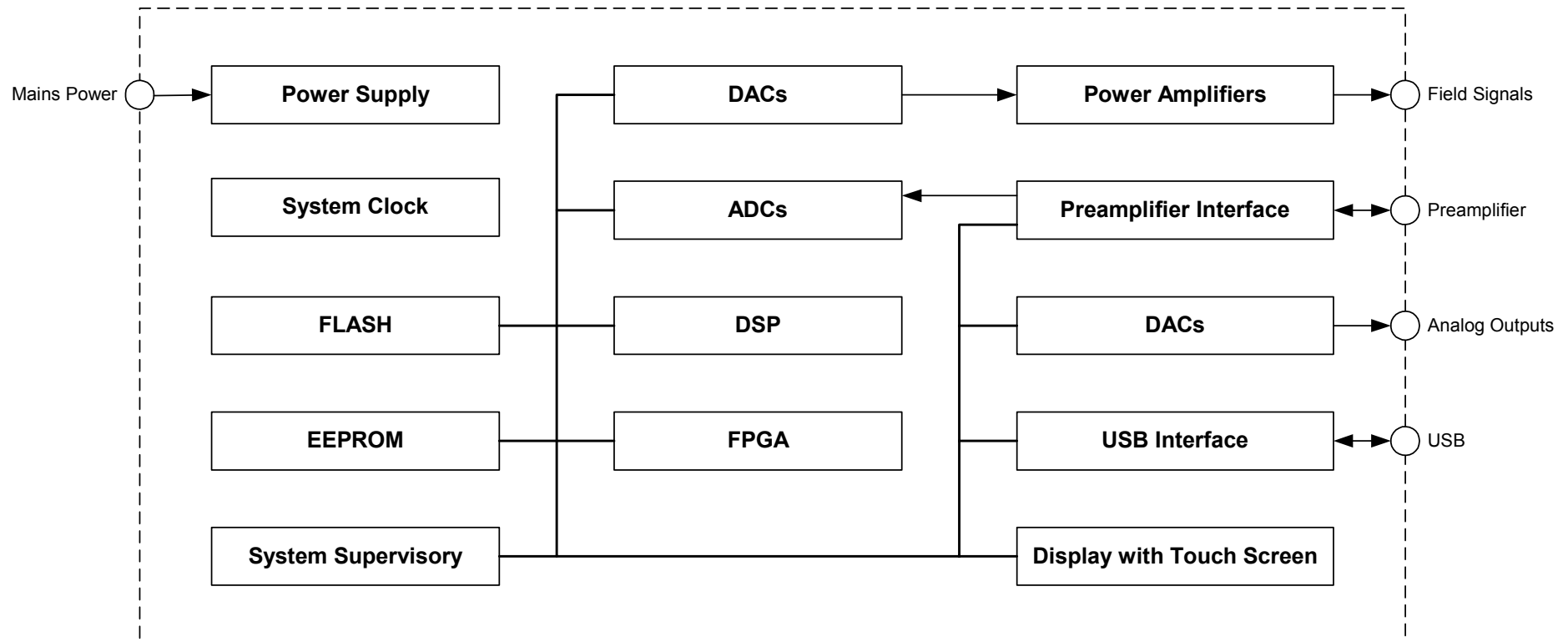


Display with Touch Screen and Menu System



Mainboard of the Main Unit

Main Unit – Block Diagram



Main Unit – Analog Interfaces

- **Three analog outputs per channel (total 24 analog outputs, 14 bit DAC)**
- **User selectable format (linear angular data or raw data)**
Using the linear angular data output eliminates the need for additional external trigonometric calculations
Using the raw data output ensures full access to the detected signals X, Y and Z, e.g. to use specific algorithms in external data processing
- **User selectable voltage swing ($\pm 5\text{ V}$, $\pm 4.5\text{ V}$, $\pm 4\text{ V}$, $\pm 2.5\text{ V}$, $\pm 2\text{ V}$)**
Useful to match the voltage swing of the analog outputs to the input voltage range of the used external data acquisition system

Main Unit – Digital Interface USB 1.1 / 2.0

- **Continuous data output**
The USB-Interface continuously transmits data packets. Each packet contains the complete output data (21 bit resolution) as well as a unique time stamp and a subsequent packet number
- **System configuration**
All settings of the CS681 may be controlled over the USB-Interface
- **Firmware upgrade**
The firmware of the CS681 is upgradeable over the USB-Interface

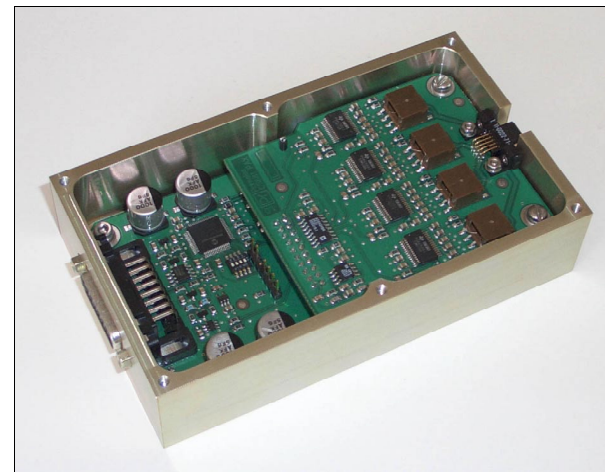


Preamplifier

- In order to avoid routing the susceptible search coil signals over a long distance, the CS681 comes with an external preamplifier (8 channels)
- Ultra low noise input stages, digital programmable gain per channel
- Transformer-coupled inputs to ensure galvanic isolation

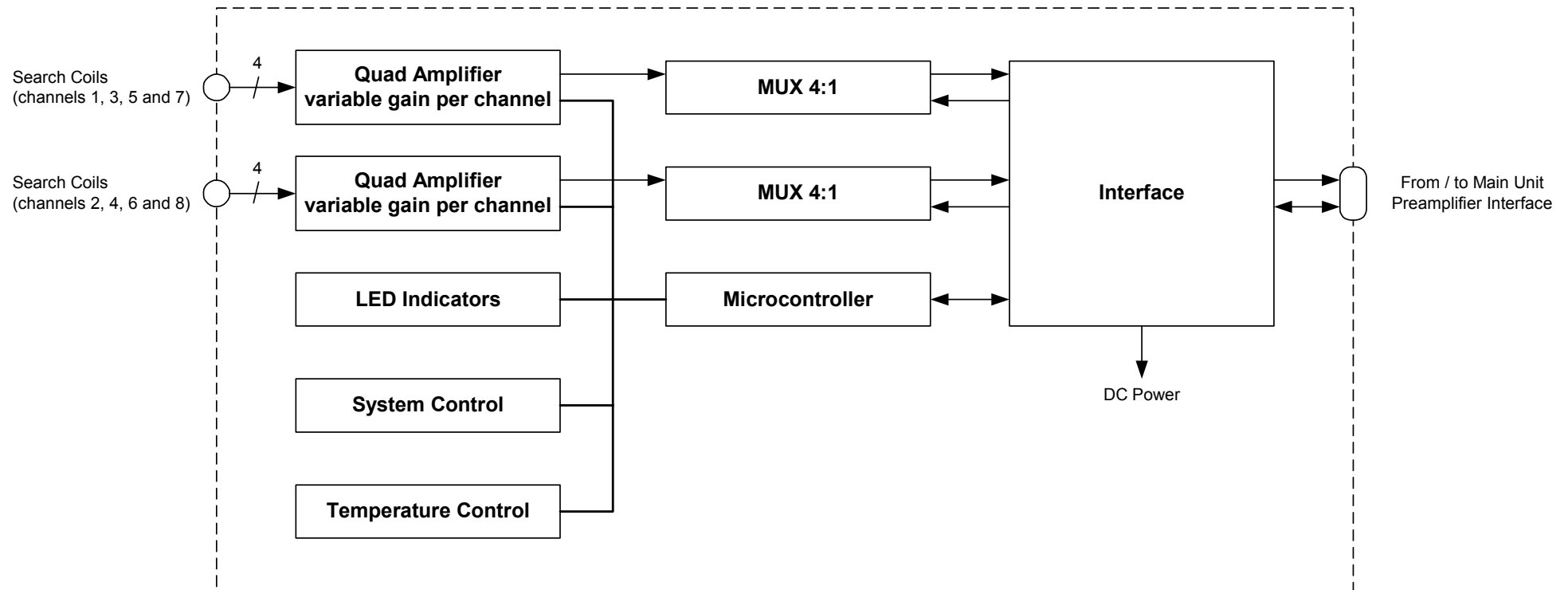


Preamplifier



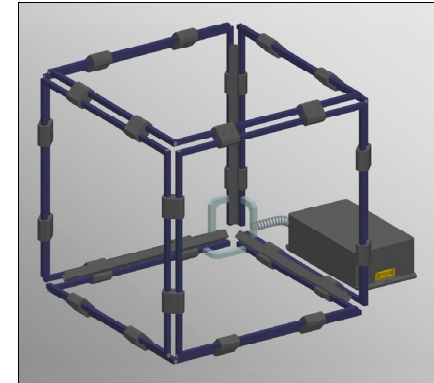
Removed Cover

Preamplifier – Block Diagram

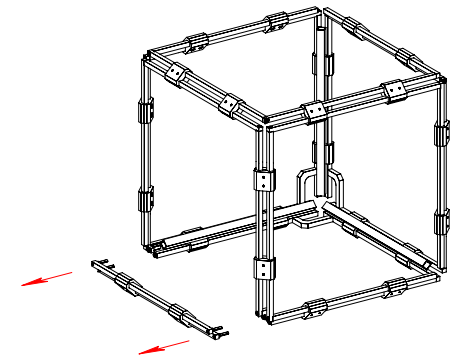


Coil Frame with Matching-Box

- 3 field coils (X-, Y- and Z-coil), composed of aluminium bars with a cross section of 8 mm
- Available edge length in the range from 250 mm to 700mm
- Various colors available
- Minimal restriction of the visual field
- Dismountable if needed for easy integration into user specific setups
- Optional removable bars to simplify the insertion of large objects (e.g. a primate chair)
- External Matching-Box for resonance tuning



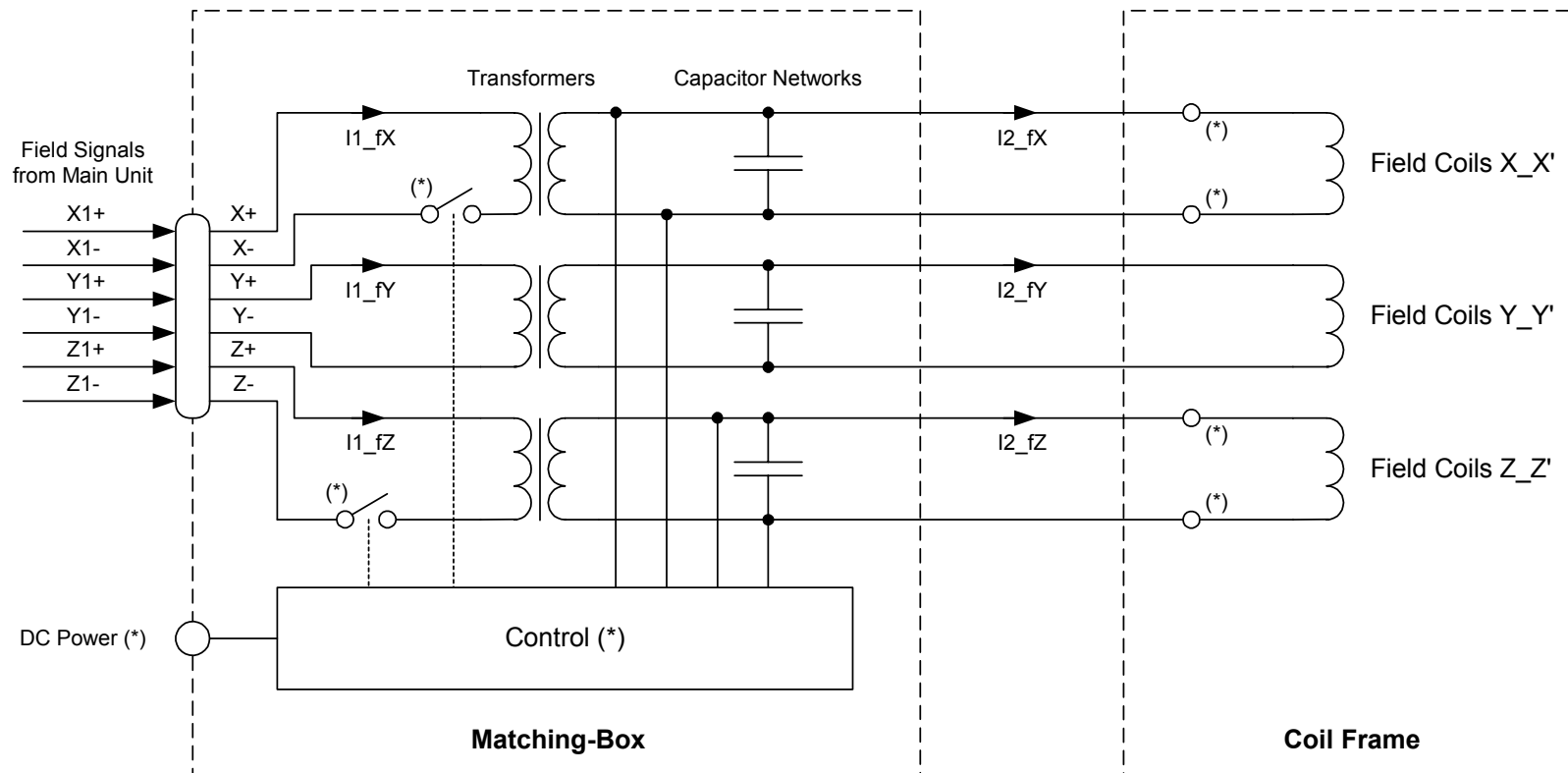
Coil Frame and Matching-Box



Removable Bars



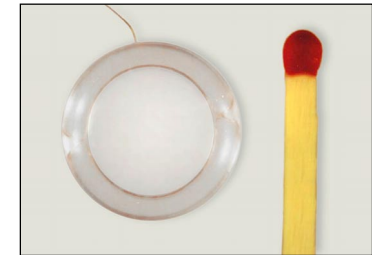
Coil Frame with Matching-Box – Block Diagram



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

Search Coils

- **Various search coils applicable in terms of dimension, geometry, material etc.**
- **Effective area in the range from 0.5 cm^2 ... 100 cm^2 , smaller coils applicable (noise increased)**
- **Scleral search coils are suitable
To measure torsion they are in a two-coil form
(frontal and sagittal plane)**
- **Manufactured by the user to comply the specific requirements**



Typical Scleral Search Coil

Included Software

- **Application software (Windows 2000 / XP)**
May be used to control the CS681 and to analyze and capture the output data over the USB-Interface as well as for firmware upgrades
- **ActiveX control**
Allows a user application software the straightforward communication with the CS681 over the USB-Interface
- **Detailed documentation of the ActiveX control (help file)**
- **Example applications for the ActiveX control (LabVIEW VI and VB source code)**



System Configuration

- **The magnetic field is tuned at the factory to ensure specified flux density and optimal homogeneity at the 3D-centre of the coil frame**
- **The user adjusts the gain(s) of the preamplifier according to the used search coil(s)**
- **Optional gain- and offset correction for the respective X-, Y- and Z-signals per channel by the user**
- **Automatic tuning of all gain- and offset settings provided**
- **Manual control of all settings over the touch screen of the display or over the USB-Interface**
- **Nonvolatile memory for 10 user specific system configurations**



System Comparison

	Typical Video-Based System (3 cameras on a headband)	Analog Search Coil System (phase-locked amplitude demodulation)	Primelec CS681 (real-time digital signal processing)
Output Data Rate	200 Hz	Approx. 500 Hz	8000 Hz / 4000 Hz / 2000 Hz (2 / 4 / 8 channels)
Latency	10 ms	Approx. 5 ms (lowpass filters)	500 us
Resolution	< 0.1° (noise limited)	< 0.01°	< 0.0002°
Noise (RMS), Full Bandwidth	< 0.1°	< 0.05°	< 0.0028°
Detection Range, Deviation < 0.5°	±30° horizontal ±20° vertical	360° horizontal ±60° vertical	360° horizontal ±70° vertical
Main Strengths	Non-Invasive Insensitive to magnetic interference Insensitive to electrical interference	Applicable on very small subjects No LOS necessary Insensitive to lightning conditions Wide detection range	Applicable on very small subjects No LOS necessary Insensitive to lightning conditions Wide detection range Ultra high accuracy and bandwidth
Main Weaknesses	LOS necessary Sensitive to lightning conditions Not applicable on small subjects Weight	Sensitive to magnetic field distortions Sensitive to electrical irradiations Fragile search coil Long term drift	Sensitive to magnetic field distortions Sensitive to electrical irradiations Fragile search coil

References

Partial list of publications, in which the used method includes a Primelec search coil system.
For further references see www.primelec.ch/ref_coilsys.htm

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Further Information

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