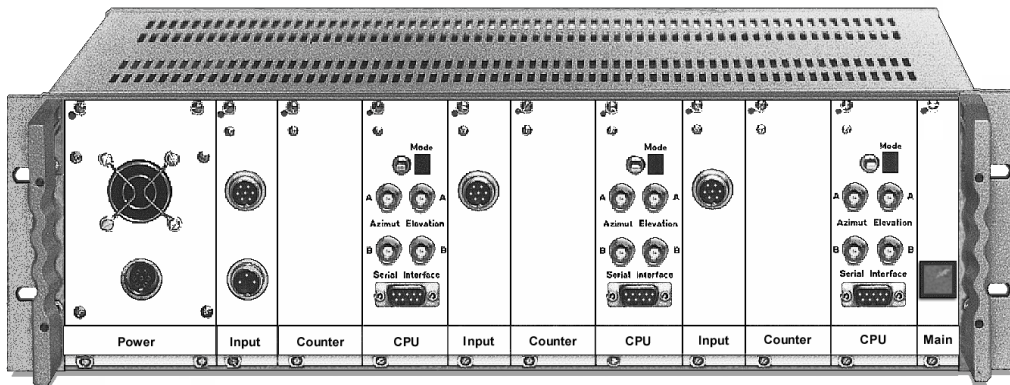


# Angle-Meter

Document Revision 990113 – January 13 1999

The Angle-Meter is the first generation of Primelec's search coil systems for the linear detection of 3D eye and head movements, which was introduced in 1989. The system was developed in close cooperation with the Vestibulo-Oculomotor Laboratory of the University Zurich.



The system's high accuracy and bandwidth ensures effortless recording of horizontal, vertical and torsional eye and head movements of unrestrained laboratory animals.

The Angle-Meter is based on an enhanced phase detection principle and ensures effortless and reliable recordings under different conditions without the need of any system adjustments by the user.

## Main Features

- Easy to use
- User friendly operation, no system configuration required by the user
- 2 + 2 + 2 recording channels (modular construction)
- Recording range 360° in the horizontal plane,  $\pm 70^\circ$  in the vertical plane
- Output data rate 400 Hz
- Resolution:  $< 0.1^\circ$  in the horizontal and vertical plane
- Noise:  $< 0.3^\circ$  peak-peak
- Microprocessor-controlled operation
- Digital synthesized field signals (crystal controlled)
- Digital and analog output data (RS-232 interface and analog outputs)
- Linear output data (angular orientation in the horizontal and vertical plane)
- Various search coils applicable without the need for any system adjustments by the user
- Various coil frames applicable
- Comprehensive customer support by Primelec
- Two years warranty

## Measuring principle

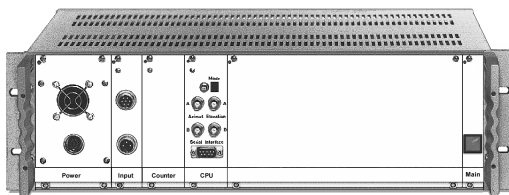
The magnetic field search coil technique introduced by Robinson [1] has become the most commonly used method for quantitative studies of eye and head movements in man and in experimental animals. The technique is based on phase-locked amplitude detection of the voltage induced in a search coil in the external ac magnetic field. The angular orientation or displacement of the search coil in three-dimensional (3D) space is detected by using two or three external magnetic fields, which are arranged in space quadrature. Demodulation of the induced signals with respect to the magnetic field directions is obtained on the basis of phase or frequency coding by driving the external magnetic fields in phase quadrature or at different frequencies. In order to obtain reproducible results, the search coil measurements have to be restricted to the uniform part of the external magnetic field.

The Angle-Meter uses a modified measuring principle. The system uses three (partly) modulated, digitally synthesized AC voltages for the magnetic field generation. The measuring plane, i.e. the plane in which the angular orientation of the search coil is faithfully detected, is determined by the plane of rotation of the magnetic field vector [2]. The demodulation of the angular orientation of a search coil is based on the phase detection of the induced voltage with respect to the phase of the rotating flux density vector [3]. This ensures almost drift-free, low noise, high-resolution output signals and an excellent system linearity.

## Concept

The Basic System of the Angle-Meter is capable to process simultaneously two search coils. The use of two additional channel pairs allows the simultaneous processing of six search coils.

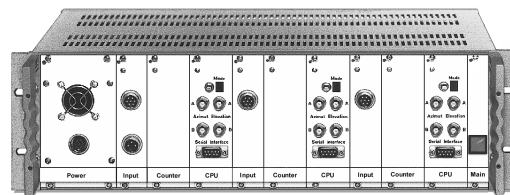
**Basic System**



Application example:

Simultaneous binocular measurement of horizontal and vertical eye position or simultaneous monocular measurement of horizontal, vertical and torsional eye position.

**Basic System plus two additional channel pairs**



Application example:

Simultaneous binocular measurement of horizontal, vertical and torsional eye and head position.

The Angle-Meter is a fully microprocessor-controlled device, designed in a modular form. The Basic System consists of the field signal generation electronics, an external preamplifier, control- and detection-electronics for two measuring channels, i.e. two search coils may be processed simultaneously.

The Basic System is expandable by the use of additional channel pairs. An additional channel pair consists of an external preamplifier, control- and detection-electronics for two measuring channels. Therefore, the Basic System may be expanded to simultaneously process four or six search coils by adding one or two additional channel pairs.

[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

[2] Kasper H.J., Hess B.J.M., Dieringer N. (1987), A precise and inexpensive magnetic field search coil system for measuring eye and head movements in small laboratory animals, J. Neurosci. Meth. 19: 115 ... 124

[3] Kasper H.J., Hess B.J.M. (1991), Magnetic search coil system for linear detection of three-dimensional angular movements, IEEE Trans. Biomed. Eng. 38: 466-475

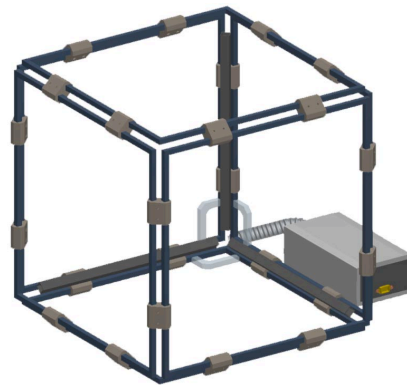
Each measuring channel processes the voltage induced in the search coil and detects the horizontal and vertical orientation of the search coil, where the output signals for the horizontal and vertical angles correlate directly proportional to the angular orientation of the search coil(s) in the external magnetic field. Thus, the system delivers linear outputs and no extra trigonometrical calculations are required. The detected angular orientations in the horizontal and vertical plane of each measuring channel are simultaneously available as linear analog voltages (BNC-connectors) and as a stream of data over the RS-232 interface (D-SUB connectors). The analog outputs allow to monitor the measurement signals on an oscilloscope, Y/t-tracer, A/D converter etc. Using the serial interface makes it easy to transmit the measuring data directly to a computer, which eliminates the use of an external A/D converter.

### Coil frame

The coil frame consists of three pairs of one-turn field coils (X-, Y- and Z-coil), arranged as a cube, which are building the inductive part of three resonance circuits. An external Matching-Box contains the capacitor networks to tune these resonance circuits. The field signals are applied to the resonance circuits and the resulting currents in the field coils generate the magnetic field.

Primelec offers coil frames in various colors, arranged as a cube with an edge length in the range from 25 cm to 70 cm. Due to the monocoque construction, the restriction of the visual field is minimal. Our coil frames can be de- and remounted, which may be helpful for user specific setups.

To ensure optimal mounting flexibility, the Matching-Box is not fixed to the coil frame. The option "Removable Bars" easily allows to open the coil frame, for example to insert an animal chair into the coil frame.



The picture shows a coil frame with an edge length of 30 cm and the connected Matching-Box.

### Search coils

The Angle-Meter allows the use of various search coils. 'Contact lenses' with eye coils are suitable, to measure torsion they are in a two-coil form (i.e. two measuring channels required). Head movements can be measured with a head coil.

The search coils may be manufactured by the user to achieve best results and highest flexibility for the specific application. Primelec offers search coils in many different shapes and sizes, but of course our system is also compatible with the search coils of third-party suppliers.

To minimize the pick up of stray signals, the preamplifier for the search coil signals is in a separate case, which can be placed near to the search coils. The preamplifier contains an automatic gain control (AGC), which allows the use of various search coils under different conditions without the need for any system adjustments by the user and ensures always an optimal signal to noise ratio of the measuring data.

### Serial interface

The serial Interface (RS-232) continuously transmits the measuring data and may also be used to toggle the magnetic field generation. Transmitting the measuring data by the serial interface to an external computer eliminates the use of additional A/D converters, which reduces the total system costs. The scope of delivery of the Angle-Meter includes a software (Win 9x) to save, analyze and display the measuring data in various representations.

**Check list - highlights in brief**

Please compare the highlights of the Angle-Meter with those of two currently available competitor systems on the market:

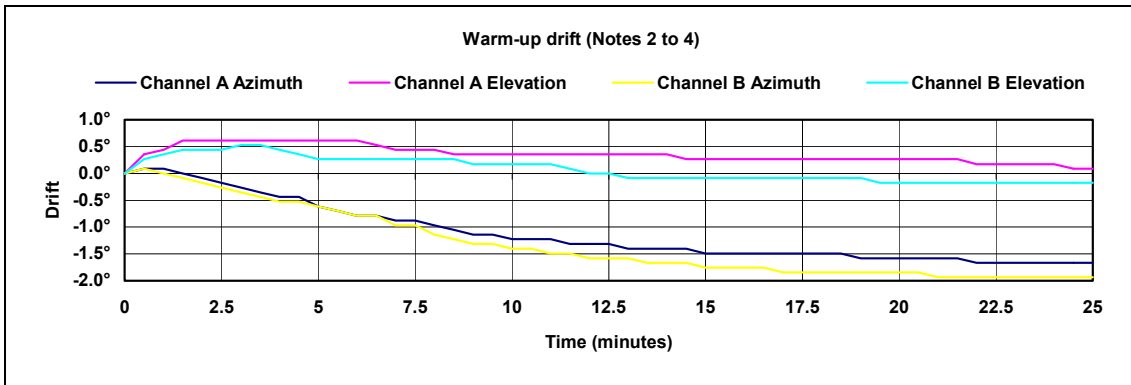
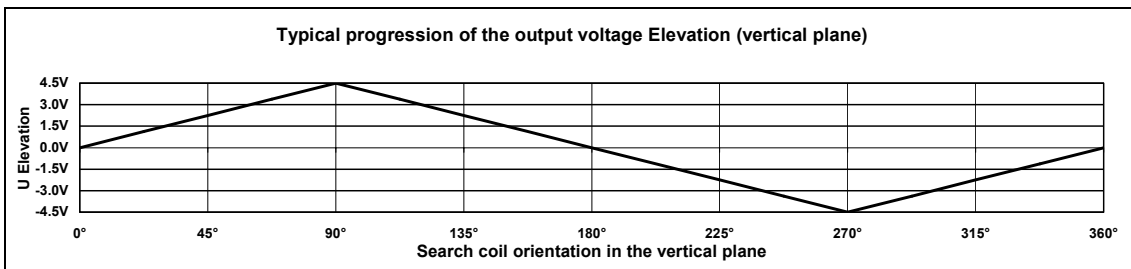
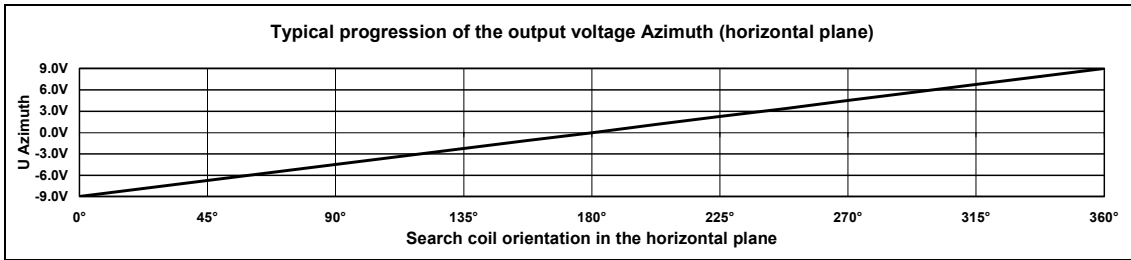
	<b>Angle-Meter</b>	<b>Competitor X</b>	<b>Competitor Y</b>
Excellent system linearity and resolution	✓	?	?
Extremely stable and reliable output data	✓	?	?
Low noise, low drift output data	✓	?	?
Linear outputs (horizontal / vertical angular orientation)	✓	?	?
Easy to handle (no potentiometers to adjust)	✓	?	?
Use of various search coils without system tuning	✓	?	?
Modular construction	✓	?	?
Simultaneous processing of up to six search coils	✓	?	?
Digital outputs (serial interface RS-232)	✓	?	?
Analog outputs	✓	?	?
Microprocessor-controlled operation	✓	?	?
External preamplifiers with AGC	✓	?	?
Coil frame available in various colors and dimensions	✓	?	?
Coil frame demountable	✓	?	?
Insensitive to illumination conditions	✓	?	?
Atraumatic for examined subjects	✓	?	?
Turntable mounting possible	✓	?	?
Two years of full warranty	✓	?	?
Lifetime technical support	✓	?	?
Engineering and manufacturing in Switzerland	✓	?	?

**Technical Data**

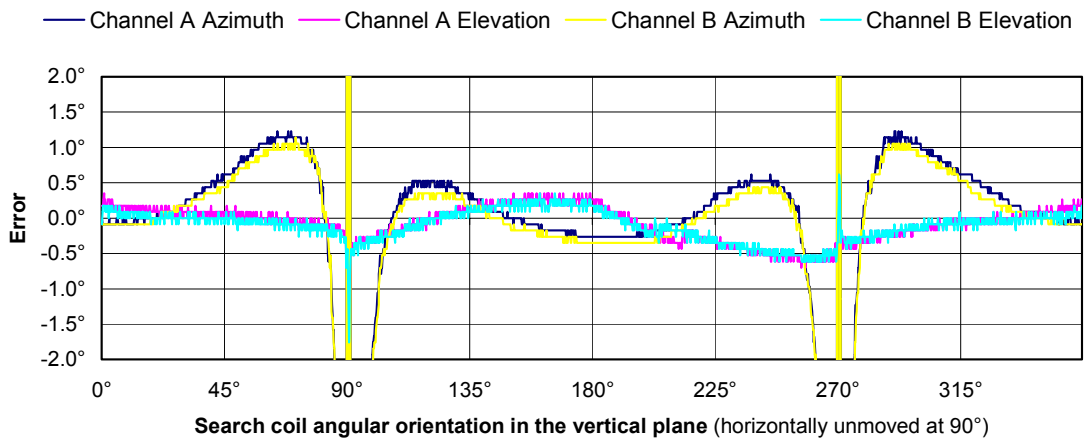
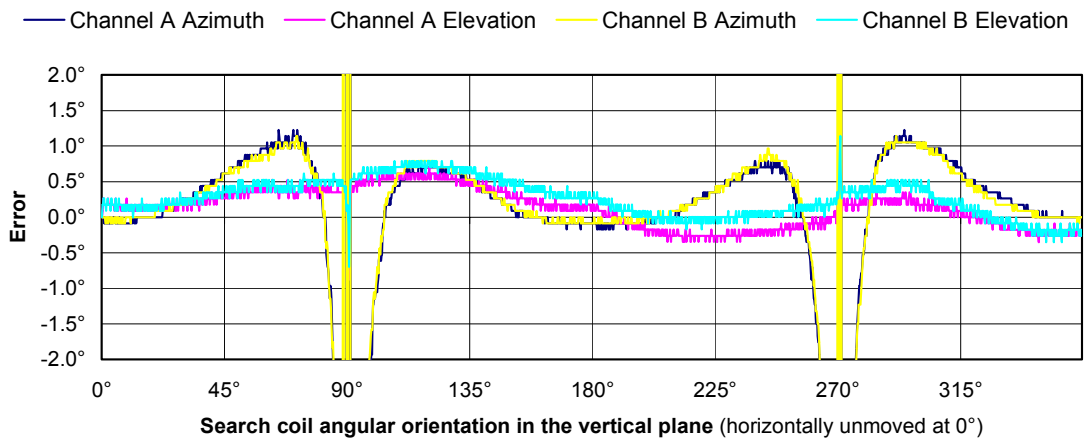
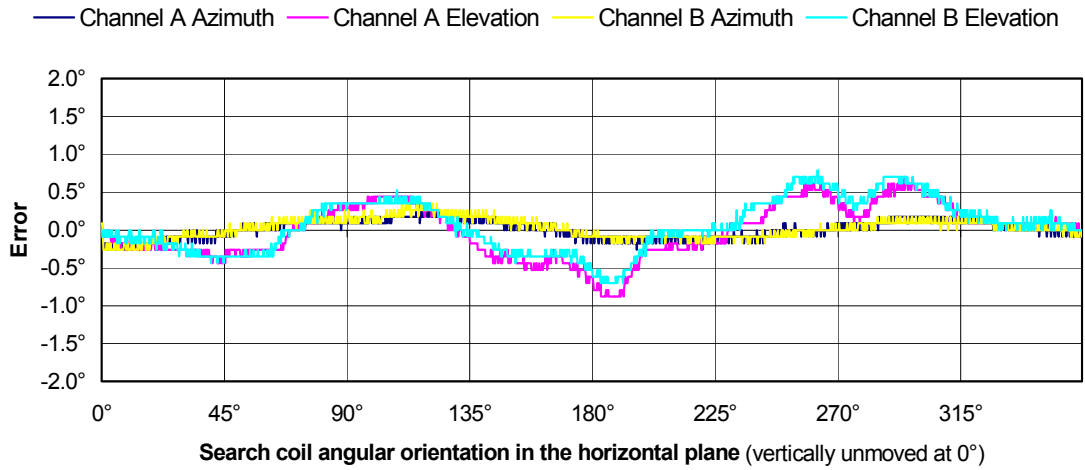
In General	
Recording Channels	Two channels in the Basic System, expandable by the use of up to two additional channel pairs to six channels
AC input voltage	230 VAC $\pm$ 10 %, 50 Hz (115 VAC $\pm$ 10 %, 60 Hz on request)
Power Consumption	300 VA max.
LED-Display	7 Segment (Mode Indicator)
Control Elements	Main switch, multifunctional toggle-switch for the mode of each CPU Plug-In
Outline Dimensions	19" / 3 HU rack mountable or desktop case, 483 x 140 x 380 mm (w x h x d)
Weight	Basic system approx. 8 kg Additional channel pair approx. 0.5 kg
Measuring Data	
Update Rate	400 Hz
Recording Range	360° in the horizontal plane $\pm$ 70° in the horizontal plane
Resolution	< 0.1°
Linearity	Horizontal < 0.7° deviation within 360° (see also diagram below) Vertical < 1° deviation between $\pm$ 70° (see also diagram below)
Noise	Horizontal < 0.1° peak-peak (see also diagram below) Vertical < 0.2° peak-peak (see also diagram below)
Drift	See diagram below
Analog Outputs	
Output Impedance	50 Ohm typical
Voltage Swing	Horizontal $\pm$ 9 V, 50 mV / ° (see also diagram below) Vertical $\pm$ 4.5 V, 50 mV / ° (see also diagram below)
Serial Interface	
In General	One serial interface (RS-232) transmits the data of 2 channels
Parameters	38'400 bps, no parity, 8 data bits, 1 stop bit

Coil Frame	
In General	Three coils with two turns each, arranged as a monocoque cube, therefore minimal restriction of the visual field
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)
Magnetic Flux Density	23 uT typical The magnetic flux density may be reduced by the user in steps of 20 % down to zero (see "Nominal output voltages" above)
Search Coils	
Material	Preferably double insulated copper wire, Ø 20um
DC-Resistance	Max. 300 Ohm
Effective Area	2.5 cm <sup>2</sup> ... 20 cm <sup>2</sup> Effective Area = $n D^2 \pi / 4$ , where n is the number of turns and D is the diameter
Weigth	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
Preamplifier	
In General	The Preamplifier is placed in a separate case and processes the signals of two search coils
Outline Dimensions	112 x 33 x 60 mm (w x h x d)
Weight	250 g

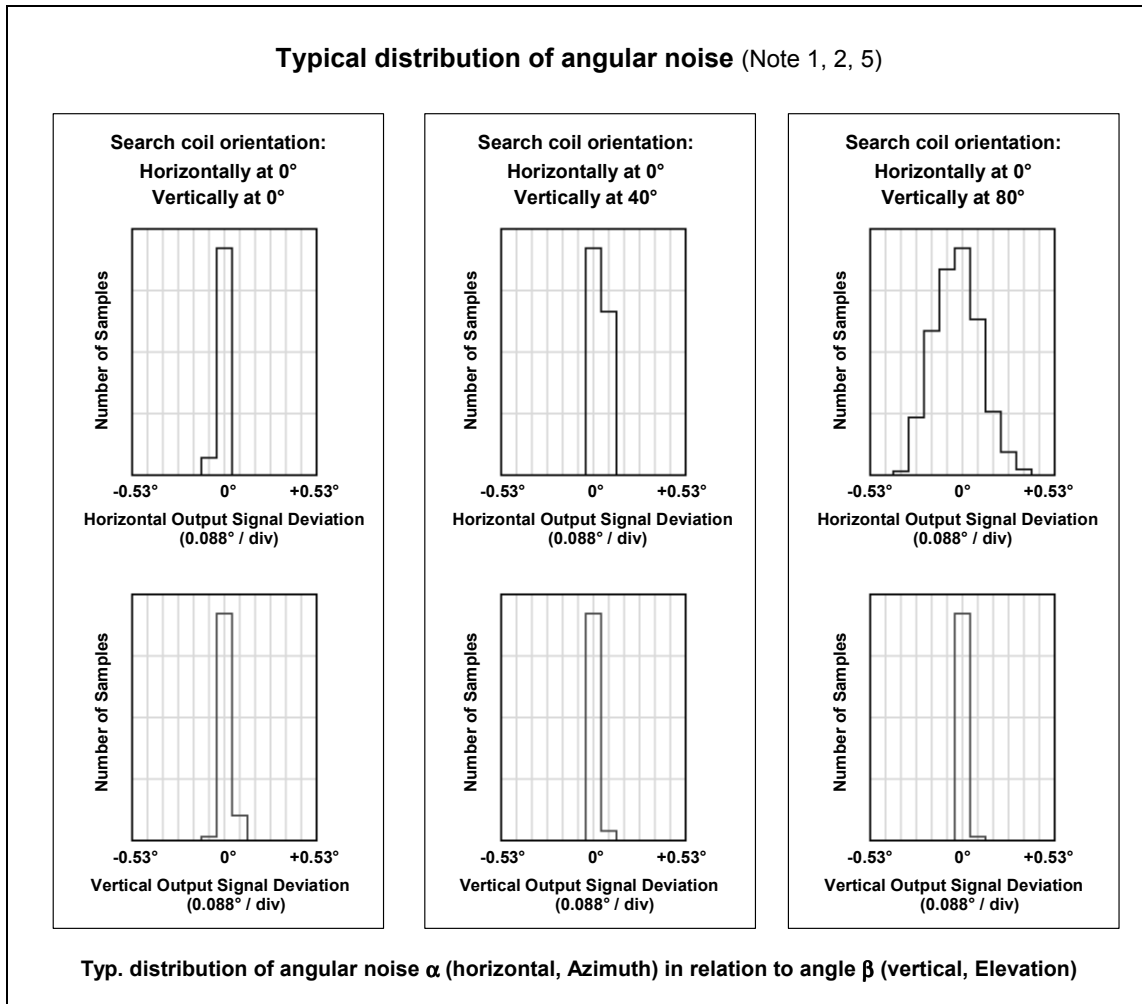
## Diagrams



### Linearity Error and Crosstalk (Note 1, 2, 4)

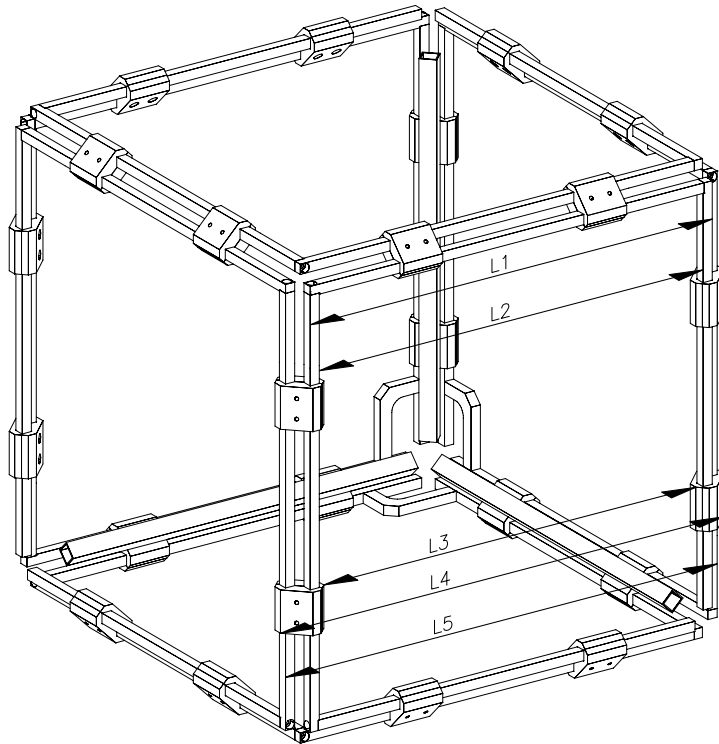






- Note 1** Measured after 15 minutes warm-up delay with stepper-motor driven search coil under software control
- Note 2** Used coil frame: formed as a cube, L1 = 700 mm  
Used search coil:  $\varnothing$  15 mm, 6 turns; placed at the 3D-center of the coil frame  
The data was acquired over the serial interface
- Note 3** Measured with 6 channels working (i.e. max. internal power dissipation)
- Note 4** Channel 1 and channel 2 in parallel at the same search coil (i.e. identical input signal)
- Note 5** Each histogram is based on a recording with a total number of samples of 12000, i.e. 30 seconds at 400 samples / second

Coil Frame – Mechanical Dimensions



L1	250 ... 700 mm
L2	L1 – 16 mm
L3	L1 – 27 mm
L4	L1 + 36 mm
L5	L1 + 26 mm

Notes:

- Dimension L1 may be specified by the customer, the other dimensions (L2 to L5) are resultant
- The coils consist of anodized aluminum bars, the color may be specified by the customer
- The drawing above is not full-scale and schematically depicts a coil frame with L1 = 350 mm

Examples (frequently used dimensions):

L1	L2	L3	L4	L5
<b>350 mm</b>	334 mm	323 mm	386 mm	376 mm
<b>500 mm</b>	484 mm	473 mm	536 mm	526 mm
<b>700 mm</b>	684 mm	673 mm	736 mm	726 mm

**Purchase Order Form**

Please complete and fax to Primelec, fax number +41 44 884 28 83

Purchase Order Number:		
Vendor ID Number:		
Date:		
Signature:		
<b>Invoice to</b>		
University / Organization:		
Name:		
Title:		
Address:		
<b>Deliver to</b>		
University / Organization:		
Name:		
Title:		
Address:		
E-mail:		
<b>Product</b>	<b>Quantity</b>	<b>Options / Comments</b>
Angle-Meter, Basic System		Mains Voltage: <input type="checkbox"/> 230 VAC / 50 Hz <input type="checkbox"/> 115 VAC / 60 Hz
Angle-Meter, Additional Channel Pair		
Coil Frame		Dimension L1:        _____ mm  Coil Color: <input type="checkbox"/> Achromatic <input type="checkbox"/> Black <input type="checkbox"/> Other: _____  Removable Bars: <input type="checkbox"/> No <input type="checkbox"/> Yes