

# Angle-Meter NT

Document Revision 060502 – May 2 2006

The Angle-Meter NT is the second generation of Primelec's search coil systems for the linear detection of 3D eye and head movements, which was introduced in 1999. The system was developed in cooperation with the Vestibulo-Oculomotor Laboratory of the University Zurich.



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

The Angle-Meter NT is based on Primelec's enhanced amplitude detection (FFT). A digital signal processor is used to detect the angular orientation of the search coils and to control the device. The completely digital controlled Angle-Meter NT provides a wide variety of settings, nevertheless the handling is very easy and user friendly.

## Main Features

- Easy to use, straightforward system configuration
- Automatic tuning of gain- and offset settings
- User friendly menu controlled operation
- 4 + 4 recording channels (modular construction), digital processing of up to 8 search coils
- Nonvolatile memory to save / recall 2 user specific system configurations
- Recording range 360° in the horizontal plane,  $\pm 80^\circ$  in the vertical plane
- Output data rate up to 4000 Hz
- Resolution  $< 0.05^\circ$
- Noise  $< 0.09^\circ$  peak-peak
- Linear angular output data (horizontal and vertical) and raw output data (signals X, Y and Z)
- Digital and analog output data (RS-232 interface and analog outputs)
- Completely controllable over the RS-232 interface, application software included
- 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.

Conventional search coil systems use analog electronics to demodulate the search coil signal. This may cause noise-, phase- and drift problems and requires relatively complex adjustments by the user. External A/D converters are required in order to obtain the angular orientation of the search coil, which increases the total system costs.

The Angle-Meter NT uses an other approach to detect the angular orientation of a search coil. Three digitally synthesized sine wave signals of different frequencies are used to generate a magnetic field. This field induces a voltage in a search coil, where the spectral frequency components of the three field frequencies are proportional to the horizontal and vertical angular displacements of the search coil relative to the system's reference frame. The spectral frequency components are obtained by computing the FFT (Fast Fourier Transformation) of the digitized search coil signal. The use of a high performance digital signal processor (DSP) allows to compute the FFT and all required trigonometric calculations in real-time. This approach offers various advantages compared to conventional systems and eliminates most of their above described weaknesses.

## Concept

The Basic System of the Angle-Meter NT is capable to process simultaneously four search coils. The use of an Add-On Detector Module allows the simultaneous processing of eight search coils.

**Basic System**



Application example:  
Simultaneous binocular measurement of horizontal, vertical and torsional eye position.

**Basic System plus Add-On Detector Module**



Application examples:  
Simultaneous binocular measurement of horizontal, vertical and torsional eye and head position or very high-speed simultaneous binocular measurement of horizontal, vertical and torsional eye position.

The Generator Module of the Basic System generates three digitally synthesized sine wave voltages of different frequencies, which are amplified by three power amplifiers within the Generator Module. These field signals are applied via the Matching-Box to the coil frame. The

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[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

generated magnetic fields (X-, Y- and Z-field) induce a voltage in the search coil(s), which is pre-processed in the external preamplifier.

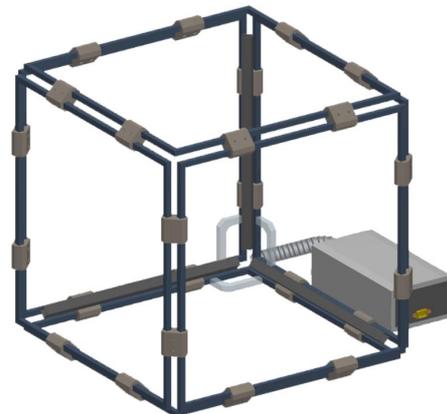
In the Detector Module, the measuring signal is digitized by an A/D converter and analyzed by a digital signal processor (DSP) in order to detect the horizontal, vertical and torsional orientation of the search coil(s). The complete detection takes less than 250 us per search coil, which allows up to 4000 measurements per second. The output data rate depends on the number of processed measuring channels (user selectable: one, two or four channels per Detector Module). The minimal output data rate (four channels per Detector Module processed) still ensures a high-speed output data rate of 1000 measurements per second.

The user may choose the system's output mode: Angular data or raw data (detected signals X, Y and Z). In the angular mode, 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, in this mode the system delivers linear outputs and no extra trigonometrical calculations are required. In the raw data mode, the detected signals X, Y and Z are scaled automatically, which simplifies subsequent data processing and ensures always an optimal S/N ratio.

Even though the enormous system flexibility of the Angle-Meter NT, the handling remains very easy and user friendly. The system contains no potentiometers to adjust gains and offsets - these settings are performed automatically by the Angle-Meter NT, where the user of course also has the opportunity to control the settings manually. The menu of the Detector Modules allows quick and easy system settings. In addition, the system may be completely controlled over the serial interface by the included software.

### 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 NT 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 can be operated

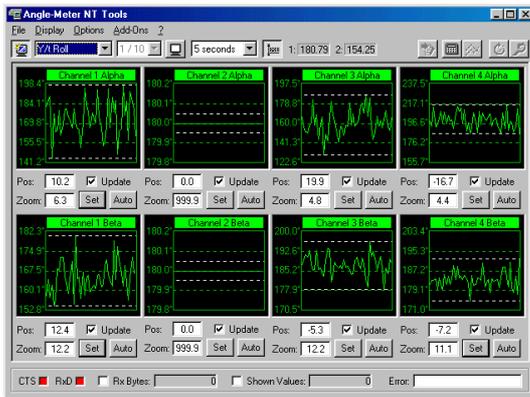
in two gain modes: AGC (automatic gain control) and fixed gain, where the gain modes may easily be selected by the user.

The AGC mode makes it possible to use 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.

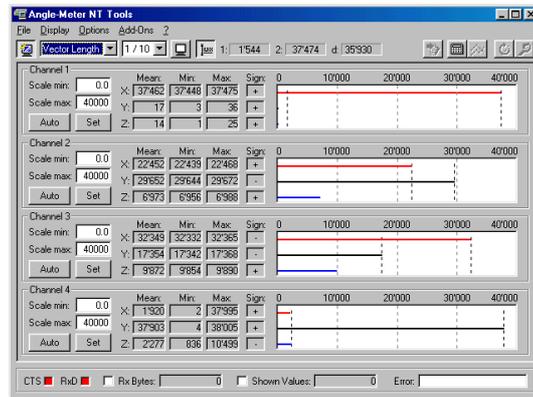
The fixed gain mode allows an offset correction to minimize the influence of picked up stray signals. The system offers auto-tuning to automatically achieve optimal values for the gain- and offset-settings.

### Software

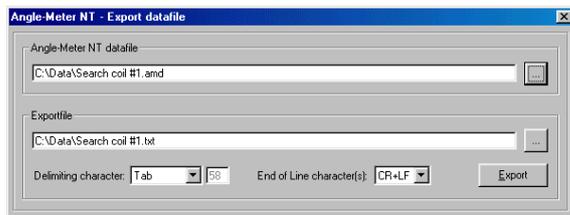
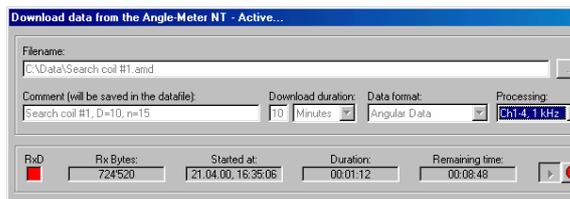
The bi-directional serial interface (RS-232) of each Detector Module continuously transmits the measuring data and may also be used to control the system. The scope of delivery of the Angle-Meter NT includes an application software (Win 9x / 2000 / XP) to save, analyze and display the measuring data in various representations and modes. In addition, the complete system may be controlled by software, i.e. all system settings can be done under software control. Below are some screenshots of the included application software:



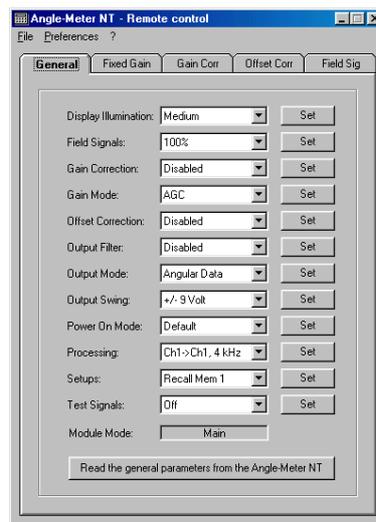
Representation of the angular data in real time



Representation of the raw data in real time



Download and export of the measuring data



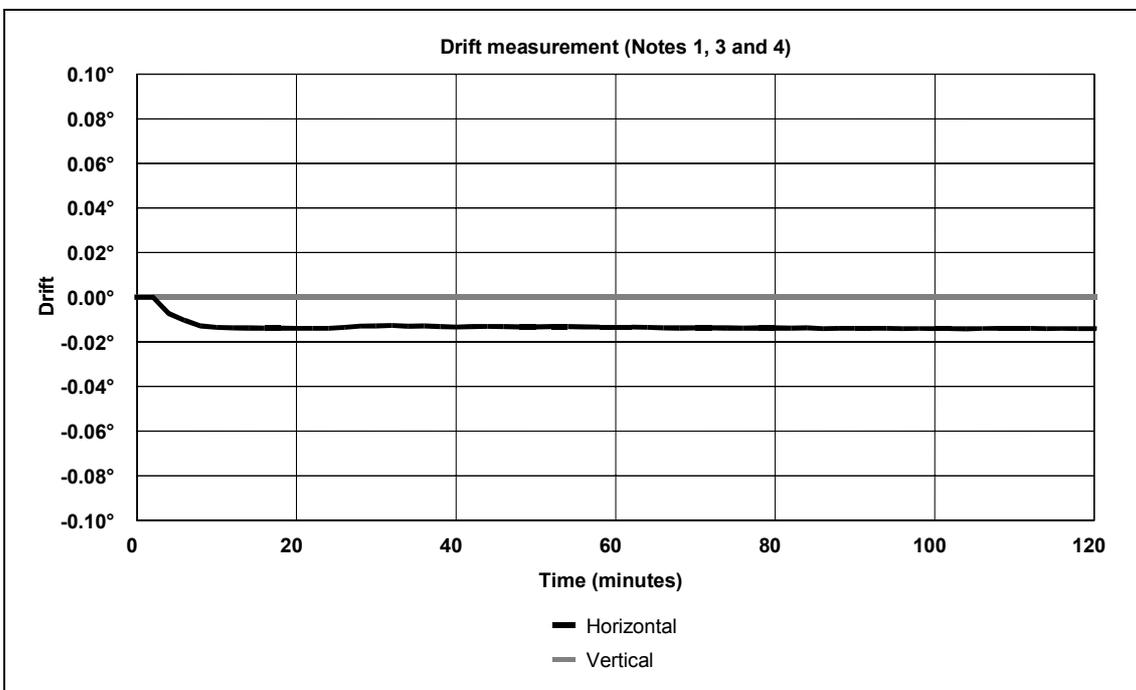
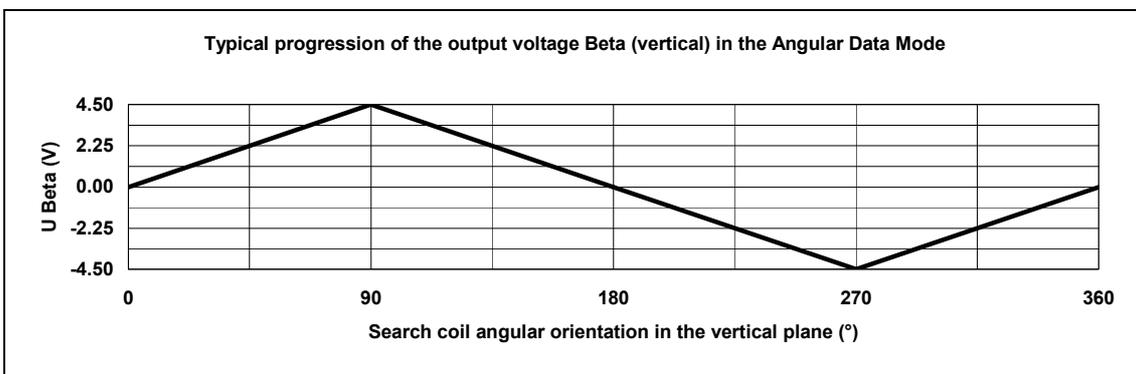
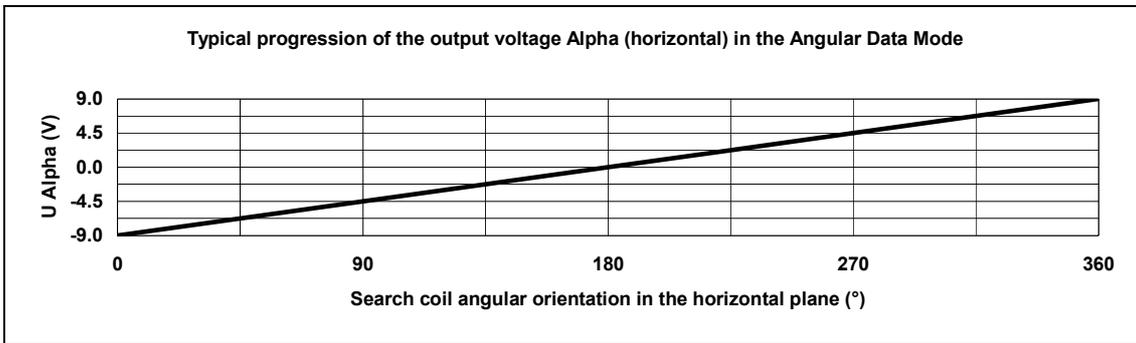
Complete system control by software

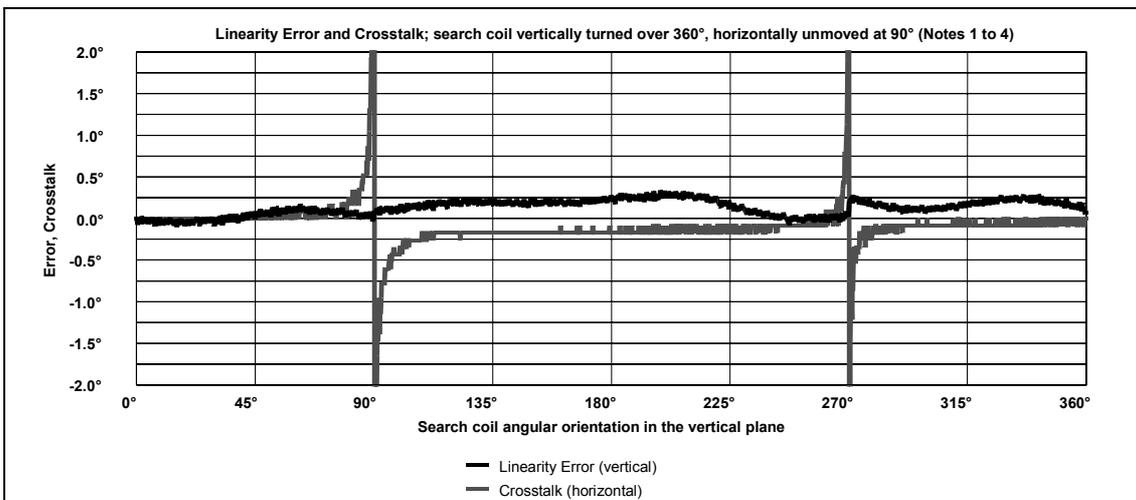
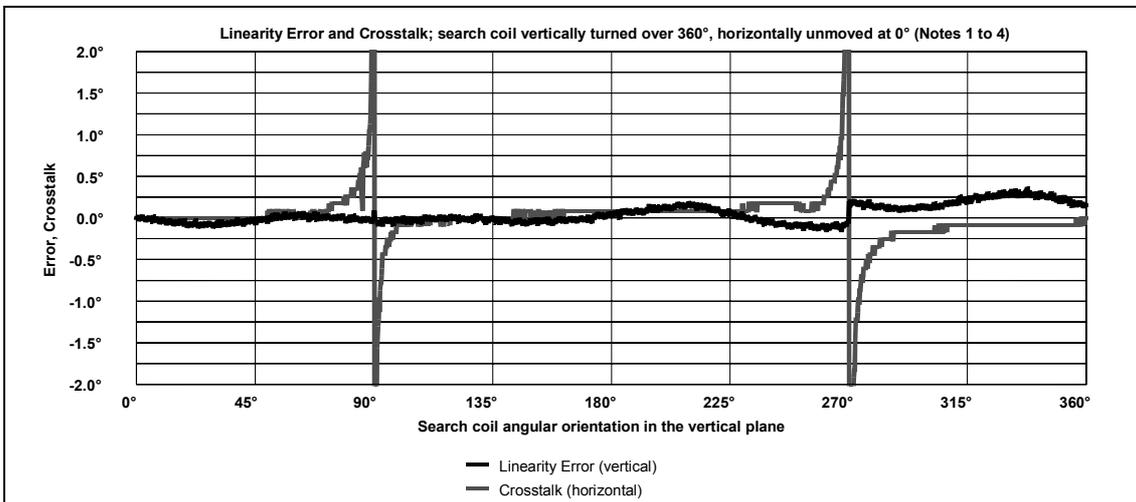
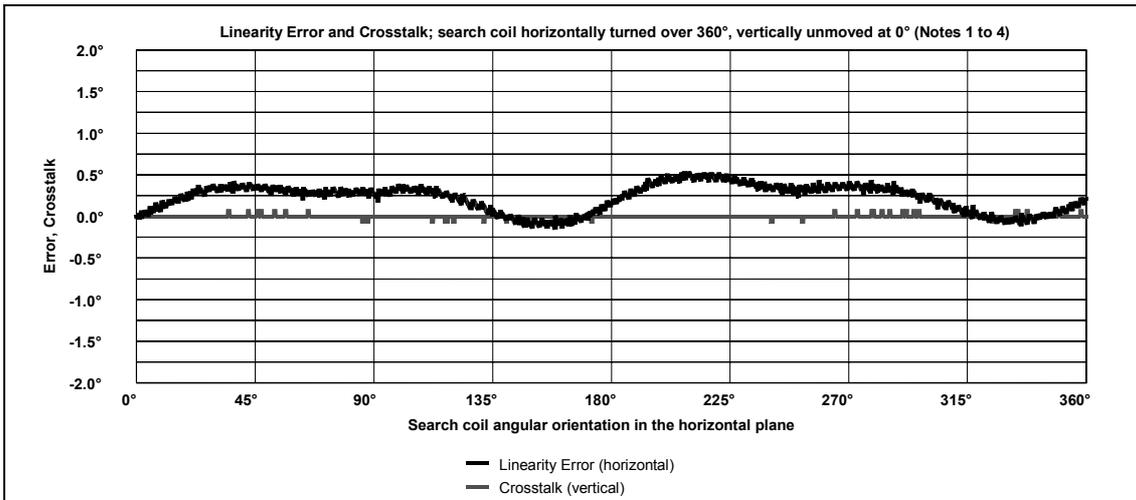
## Specifications

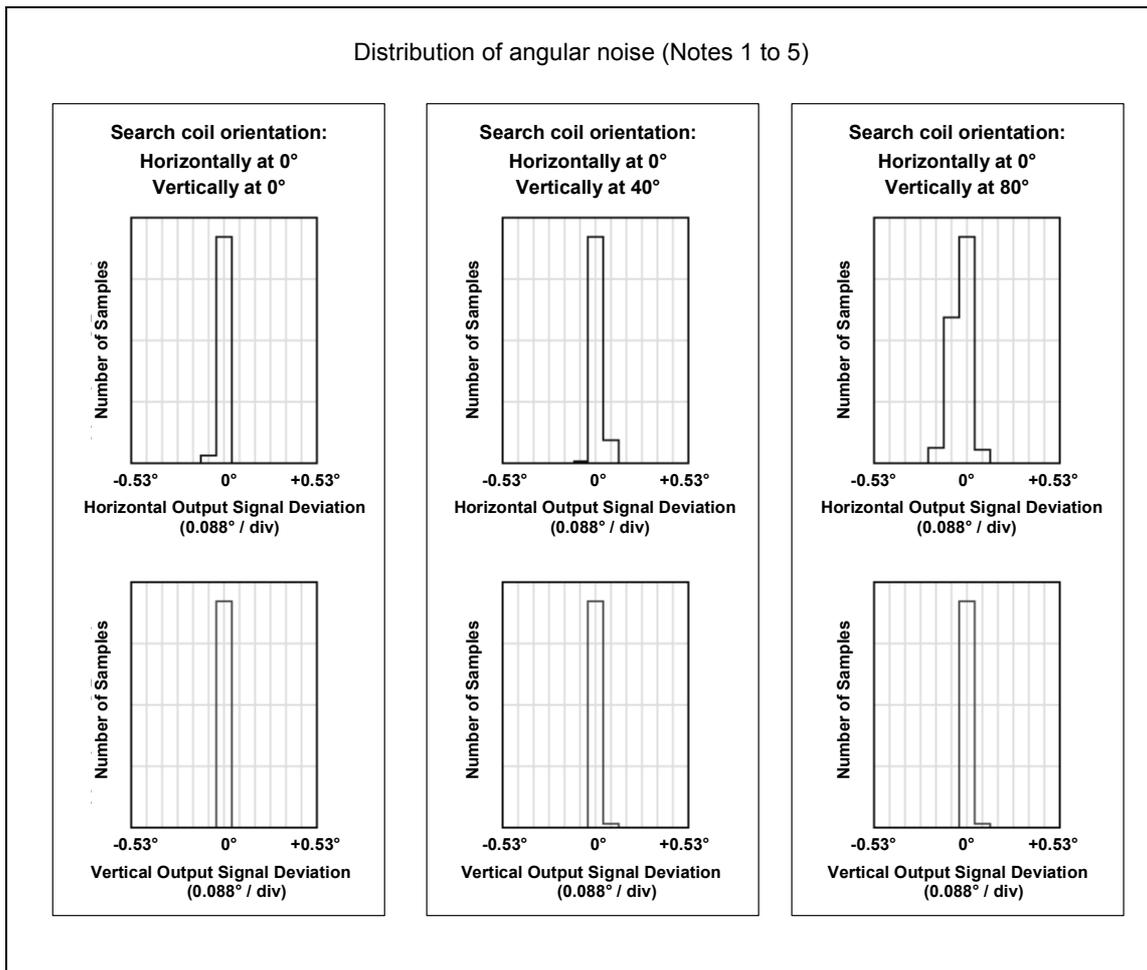
| In General              |  |
|-------------------------|--|
| Recording Channels      | Four channels in the Basic System, expandable by the use of an Add-On Detector Module to eight channels.<br><br>Applications using more than eight measuring channels are also practicable, please contact Primelec for details.       |
| AC input voltage        | 230 VAC $\pm$ 10 %, 50 Hz (115 VAC $\pm$ 10 %, 60 Hz on request)   |
| Power Consumption       | 200 VA max. during normal operation, 5 VA max. during Standby  |
| LC-Display              | 2 x 16 characters, backlight intensity selectable by the user  |
| Control Elements        | Main switch at the rear panel, Power On / Standby switch, multifunctional rotary-/ push-button for the menu of each Detector Module (operation may be locked by the user)  |
| Outline Dimensions      | 19" / 3 HU rack mountable or desktop case,<br>483 x 140 x 380 mm (w x h x d)   |
| Weight                  | Basic System approx. 10 kg,<br>Add-On Detector Module approx. 1 kg   |
| Measuring Data          |  |
| In General              | The output format of the measuring data can be selected by the user (linear angular data for the horizontal and the vertical plane or signed vector lengths for the X-, Y- and Z-signals)  |
| Recording Range         | 360° in the horizontal plane<br>$\pm$ 80° in the vertical plane  |
| Resolution              | < 0.05°  |
| Drift                   | < 0.2° during warm-up (see also diagram below)   |
| Linearity               | Horizontal < 0.5° deviation within 360° (see also diagram below)<br>Vertical < 0.3° deviation between $\pm$ 70° (see also diagram below)   |
| Noise                   | < 0.1° peak-peak (see also diagram below)  |
| Analog Outputs          |  |
| Update Rate             | Depending on the number of processed channels, user selectable:<br>- 4000 Hz (1 channel per Detector Module processed)<br>- 2000 Hz (2 channels per Detector Module processed)<br>- 1000 Hz (4 channels per Detector Module processed) |
| Voltage Swing           | User selectable,<br>$\pm$ 2.5 V, $\pm$ 4.5 V, $\pm$ 5 V, $\pm$ 9 V, $\pm$ 10 V   |
| Output Impedance        | 50 Ohm typical   |
| Serial Interface RS-232 |  |
| In General              | The bidirectional serial interface (RS-232) of each Detector Module transmits the measuring data and may be used to control the system   |
| Parameter               | 115200 bps, 8 data bits, 1 stop bit, no parity<br>Hardware handshake (RTS / CTS)   |

| Field Signals           |   |
|-------------------------|---|
| In General              | Three sine wave field signals (crystal-controlled digitally synthesized), amplified by three physically separated power amplifiers with symmetrical outputs   |
| Frequencies             | 80 kHz (X-Axis), 96 kHz (Y-Axis) and 120 kHz (Z-Axis)   |
| Nominal Output Voltages | Depend on the dimension of the used coil frame, where the nominal output voltages are tuned at the factory to achieve the specified magnetic flux density (see "Nominal magnetic flux density" below) and an optimal field homogeneity at the 3D-centre of the coil frame.<br><br>The factory-tuned nominal output voltages may be attenuated in steps of 20 % down to zero by the user |
| 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   | 15 uT typical<br>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          | 1 cm <sup>2</sup> ... 32 cm <sup>2</sup><br>Effective Area = $n D^2 \pi / 4$ ,<br>where n is the number of turns and D is the diameter  |
| 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   |
| Preamplifier            |   |
| In General              | The preamplifier is placed in a separate case and can process four search coils. It can be set to AGC or fixed gain by the user.  |
| Power Supply            | ±5 V, ±500 mA max. (power supply is provided by the Detector Module)  |
| Outline Dimensions      | 100 x 40 x 200 mm (w x h x d)   |
| Weight                  | 830 g   |

## Diagrams







**Note 1:** Measurement executed with 8 channels working (i.e. max. internal power dissipation). The data was acquired over the serial interface. Measuring channel 1 was used, where the performance of all measuring channels is identical. Settings:

- Field signals at 100 % of their nominal value
- Gain Correction disabled
- Gain Mode AGC
- Offset Correction disabled
- Output Mode Angular Data
- Output Filter disabled
- Output Swing  $\pm 9$  V
- Processing Mode Ch1  $\rightarrow$  Ch4

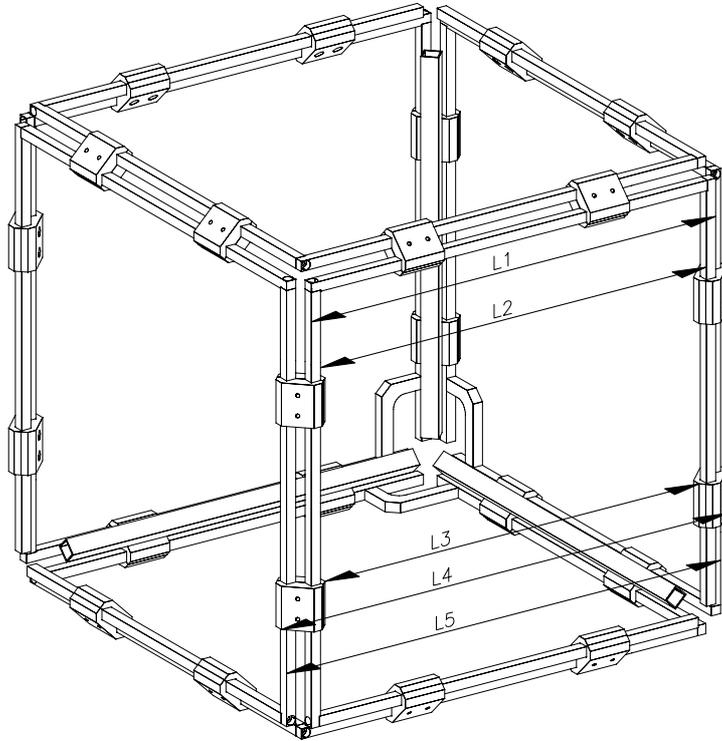
**Note 2:** Measurement executed with a stepper-motor driven search coil under software control

**Note 3:** Used coil frame formed as a monocoque cube,  $s = 70$  cm

**Note 4:** Used search coil with an effective area =  $10.8 \text{ cm}^2$  ( $\varnothing 37\text{mm}$ , 1 turn), DC-Resistance = 7 ohm, placed at the 3D-center of the coil frame

**Note 5:** Distribution of angular noise based on 5000 continuously acquired samples

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 |

Coil frame – Option “Removable Bars” to open the frame, for example to easily insert an animal chair

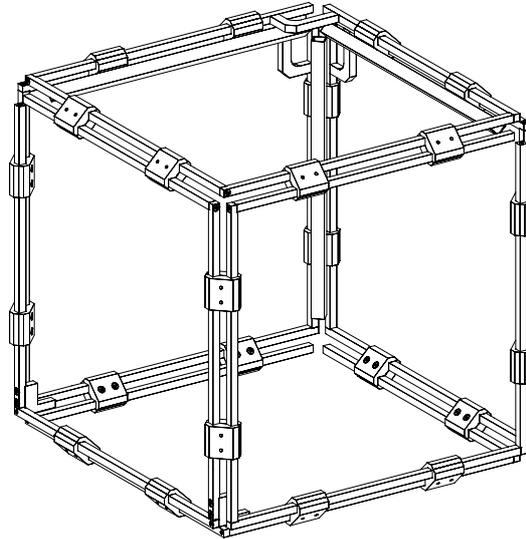


Figure 1

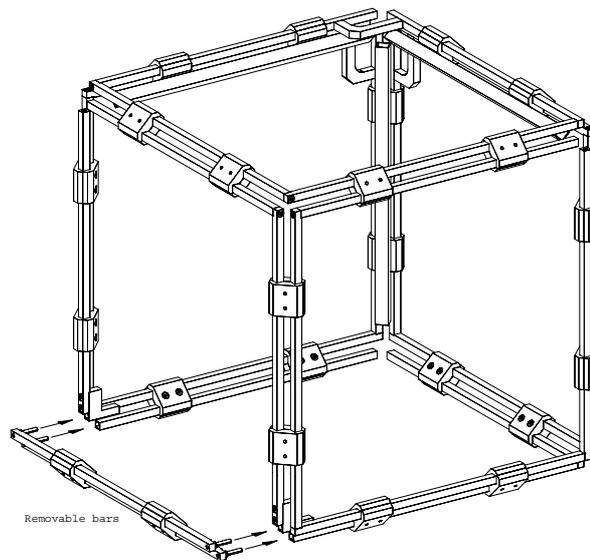


Figure 2

Notes:

- One bar per frame X and Z is removable to open the coil frame (see figure 2)
- No screws or cables have to be released to open the coil frame
- The Matching-Box requires an external power supply (12 VDC, AC power adapter included)
- The drawings above are not full-scale and schematically depict a coil frame with  $L1 = 350$  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:                                    |                 |  |
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| <b>Deliver to</b>                         |                 |  |
| University / Organization:                |                 |  |
| Name:                                     |                 |  |
| Title:                                    |                 |  |
| Address:                                  |                 |  |
| E-mail:                                   |                 |  |
| <b>Product</b>                            | <b>Quantity</b> | <b>Options / Comments</b>  |
| Angle-Meter NT,<br>Basic System           |                 | Mains Voltage: <input type="checkbox"/> 230 VAC / 50 Hz<br><input type="checkbox"/> 115 VAC / 60 Hz  |
| Angle-Meter NT,<br>Add-On Detector Module |                 |  |
| Coil Frame                                |                 | Dimension L1:        _____ mm<br><br>Coil Color: <input type="checkbox"/> Achromatic<br><input type="checkbox"/> Black<br><input type="checkbox"/> Other: _____<br><br>Removable Bars: <input type="checkbox"/> No<br><input type="checkbox"/> Yes |