Elekta Neuromag®

Service Manual

Nov 4, 2008

ELEKTA

Contents

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CHAPTER 1

Introduction

1.1 Purpose of this manual

This service manual is intended to provide instructions for the maintenance and troubleshooting of the Elektra Neuromag MEG device.

Note: Service of the device should only be carried out by certified service engineers.

1.2 Safety instructions

Warning: This section contains important information concerning the safe service of the system and maintaining reliable operation. Read the instructions entirely before servicing the system.

1.2.1 Properties of helium

The dewar is a vacuum-insulated vessel containing liquid helium at a cryogenic temperature. Since the cold liquid is potentially dangerous, certain precautions must be made to assure completely safe operation of the device.

- Helium, liquid or gas, is nonflammable and nontoxic.
- Helium is one of the noble gases (He, Ne, Ar, Kr, Ra).
- Helium gas is odorless and colorless.
- Helium gas is seven times lighter than air.

Warning: Helium gas is not life-supporting: it may replace air thus reducing the relative oxygen content in closed rooms if evaporated rapidly, resulting in a risk of suffocation.

- Boiling point is 4.2 K (–269°C or -452°F).
- Density of liquid helium is 0.125 kg/liter.
- Liquid helium evaporates very easily (latent heat of evaporation is 20.9 kJ/kg = 2.6 kJ/liter).
- One liter liquid helium corresponds to approximately 750 liters of gas (+20°C, 101,3 kPa).

Warning: Skin contact with liquid helium or cold gas or cooled objects may cause severe frostbite.

- Flow of cold helium gas makes a very good thermal contact with any surface it passes by; unprotected skin cools below freezing point in seconds.
- Dangerous pressures may arise as a result of rapid vaporization inside closed vessels.
- Liquid helium can cryopump other gases such as nitrogen, oxygen, and water vapor, which solidify at liquid helium temperature. This may lead to the blocking of the vents and consequently to the buildup of dangerous pressures in cryogenic vessels.

1.2.2 Warnings concerning the dewar and cryogenics

Warning: The structural integrity of the dewar should not be damaged in any way. Absolutely no holes may be drilled on the dewar.

Warning: The dewar must not be opened to atmospheric pressure under any circumstances.

Warning: The exhaust line must be open at all times.

Warning: To prevent frostbite, avoid contact with liquid helium or exhaust helium gas or any object that has recently been in direct contact with liquid or evaporated gas. Wear protective gloves and safety goggles.

Warning: Do not leave anyone alone inside a closed magnetically shielded room (MSR) without the presence of another person outside the room!

1.2.3 Cryopumping

At liquid helium temperature all common materials are solid. This means that the vapor pressure of for example the atmospheric gases (nitrogen, oxygen, water) is practically zero in any volume containing liquid helium, which leads to *cryopumping* of these gases: any helium vessel left open to the atmosphere will very effectively suck in large amounts of these gases. Water freezes and may block the helium vessel or a transfer siphon. Oxygen in the probe unit dewar causes large irregular low frequency drifts of MEG signals because the magnetic susceptibility of the paramagnetic oxygen in its solid form is very high.

Note: To prevent cryopumping, observe the following precautions:

- **All helium vessels must be sealed from the atmosphere and properly vented, via a back flow or valve or a sufficiently long and narrow exhaust tube.**
- **Do not leave the fixed siphon at the top of the dewar open. Block the opening with the dedicated plug when not pumping helium.**
- **Do not lead the boil-off tube vent directly into the room. Use silicon hose tube to lead the exhaust vent out from the magnetically shielded room. If the hose breaks during transfer, replace it with a new hose as soon as possible.**
- **Do not remove the fixed siphon or the boil-off tube from the top plate. The opening must be plugged with rubber bungs (provided in the Cryogenic Accessories Kit) if the fixed siphon or boil-off tube are ever removed even for a short amount of time.**
- **If the safety exhaust rupture membrane accidentally breaks, the opening must be plugged with a large rubber bung (provided in the Cryogenic Accessories Kit) and the membrane replaced.**

1.2.4 Electrical safety

All Elekta Neuromag® SQUID sensor electronics are operated using low-voltage (max. 15 $V_{=}$, 24 $V_{\sim}$) power supplies connected to the mains through an isolation transformer. To avoid electrical interference, most parts are shielded and grounded (class I according to IEC 60601-1). The probe unit is operated inside a magnetically shielded room to avoid electromagnetic interference.

Subject connections

All applied parts of MEG equipment connected to the subject are made of electrically insulating materials only. They are classified as body floating (BF) type according to IEC 60601-1.

The helmet-shaped sensor assembly is located inside a double-walled isolating (fiber reinforced plastic, vacuum gap) dewar, making no electrical contact to the subject. The device does not generate radiation. During the experiment, it is not possible for the subject to get in contact with grounded parts.

Head position coils on small printed circuit boards are spiral-shaped. The coils are connected to isolated leads and cast with isolating epoxy. No electrical contact to the subject is thus made. Current fed to coils is typ. 70 ⌠A, and the resulting field less than 1 nT.

The EEG subsystem contains an applied part of BF type in galvanic contact with the subject. The applied part has been carefully designed and built to fulfill the safety regulations as set by international standards IEC60601-1 and IEC60601-2. The EEG preamplifiers are optically isolated, and the power supply of the EEG preamplifiers is provided with safety isolation transformer.

Warning: To eliminate any risk of electrical shock hazard, the EEG subsystem must be properly installed by authorized service personnel and used as part of Elekta Neuromag® system according to manuals and assembly instructions. Internal cabling must not be changed.

Note: The EEG subsystem cannot be used as a standalone system outside of the magnetically shielded room.

There are no internal operator-serviceable parts inside. Head position indicator coils, electrode caps, headboxes, and electrode interface in the side panel of the gantry are the only operator-accessible parts of the EEG subsystem. Use only headboxes and electrode caps supplied with the system or available as options.

Power supplies and grounding

Warning: The power supply of the electronics must be connected only to the power outlets inside the electronics cabinet which are connected to the mains via an isolation transformer. Internal power cabling must not be changed.

Warning: The 3D-digitizer power supply must be connected to mains via an isolation transformer supplied with the Elekta Neuromag® system.

The main electronics is powered through medical safety-isolating transformer connected to electronics cabinet outlets. Therefore, internal power cabling must not be changed. For schematic diagrams of the powering, see Figure A.8 and Figure A.9.

Warning: The isolation.transformers also provide step-up or step-down voltage conversion if needed. Inside the main electronics cabinet the voltage is 230 V~.

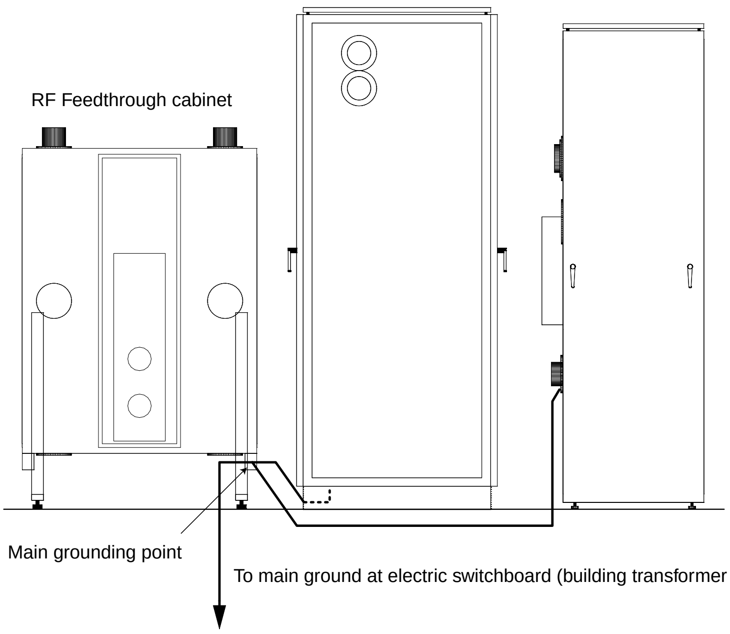

Figure 1.1 Grounding of the system

Warning: The RF line filters in the stimulus cabinet contain large capacitors. Thus voltage may remain across terminals even after the power has been switched off from the filter. The filters have built-in resistors which discharge the terminals in less than 10 seconds. All shielding covers must be in place before applying power to the filter. The filters may only be permanently installed; mains plug connection of the filter is prohibited.

The power supply units are protected by mains (primary) fuses. All fuses are accessible at the back plane of the MEG preamplifier power supply unit with the correct values of the fuses marked in the immediate vicinity. A “T” before the rated current in amperes indicates slow (time-lag, slow blow) type and a “F” fast type. If no type has been indicated, use fast type fuses. Refer to Appendix A.

Warning: To avoid risk of fire and electric shock, **always** use only correctly-rated fuses as replacement.

The system, except for the EEG-applied parts discussed below, is permanently grounded (class I equipment according to IEC 60601-1) at a single point (main grounding point) located at the filter unit cabinet between the electronics cabinet and the magnetically shielded room. See Figure 1.1.

Warning: The grounding cables must not be disconnected.

Note: The system must not be grounded to any other place than the grounding point. This is very important since otherwise ground loops will be formed resulting in artefacts in the measurements.

The grounding system of Elekta Neuromag® has been carefully designed and realized, see Figure 1.1. Do not add any equipment to the system or change any cabling without considering the possible side-effects. If in any doubt, contact Elekta Neuromag.

The applied part of EEG is electrically floating, in other words, isolated from ground. It must not be grounded in any circumstances. For potential equalization between the isolated preamplifier and the patient it is necessary to connect the patient to the isolated signal ground of the preamplifier. For that purpose, a terminal labelled ”GND” is available in the electrode interface panel. To limit the patient current flowing through that terminal to a safe level, the preamplifier signal ground connection is provided through a current-limited ground driver of the preamplifier. The isolated preamplifier signal ground is not directly accessible when headboxes and electrode caps supplied with the system - or which are available as options - are used. The isolated preamplifier signal ground, which is only available internally, must not be connected directly to humans as the maximum allowable current may be exceeded in a fault condition.

Warning: Do not connect any of the electrode inputs of the side panel or the headbox to actual ground (for example the wall of the magnetically shielded room). Care must be exercised to avoid contact of conducting parts of the electrodes, including REF and GND electrodes, to ground or other conducting parts which may be grounded or become live at mains voltage. Do not ground the subject to actual ground. Do not place conducting grounded objects so the that someone might touch them while connected to the equipment.

Auxiliary user-supplied equipment

To avoid risk of electrical shock, equipment supplied by the user and connected to humans must comply with isolation requirements similar to or better than this system. For connection of these devices, isolated and filtered power outlets are provided in the stimulus cabinet. Maximum current available is 10 A (total).

Warning: The applied parts of user-supplied equipment must be of BF type or cardiac floating (CF) type and they must fulfill the norms of IEC 60601-1 for medical electrical equipment. Although the individual devices fulfill the leakage current requirements set forth in standards, a possible hazard exists caused by the summation of leakage currents when several pieces of equipment are interconnected. Also, other equipment connected to the same stimulus trigger interface unit must fulfill the requirements of IEC 60601-1.

The power outlets in the electronics and stimulator cabinets connected to the isolation transformers (if installed) may only be used for the connection of system components or equipment needed during service and maintenance operations or for compatible user-supplied auxiliary equipment (stimulus cabinet).

1.2.5 Mechanical safety

The weight of the fully loaded dewar including liquid helium and the dewar supporting cradle moving with the sensors is approximately 200 kg. To ensure that the dewar is prevented from falling down from the seated measurement position under any circumstances it is equipped with two completely separate and parallel support mechanisms both of which alone can withstand at least a fourfold overload compared with the normal working condition.

Warning: The dewar position must not be changed while the patient, patient chair or any other person is under the gantry.

1.3 Required tools

1.3.1 General tools

The following tools are required to service Elekta Neuromag. Please make sure you have these tools available before you start any service procedures.

- Set of Phillips screwdrivers
- Set of Torx screwdrivers
- Set of PoziDriv screwdrivers
- Set of Slotted screwdrivers
- Set of wrenches (metric)
- Tongs
- Pliers
- Portable metal saw
- File
- Set of needle files
- Tweezers
- Set of hexagonal keys (metric)
- Ring spanner set
- Lock-jaw pliers
- Digital multimeter, with true RMS readout
- Tape measure
- Wire stripper
- Needle-nose pliers
- Soldering iron
- Flashlight
- Scissors
- Sheath knife
- Ethernet cable
- Modem cable
- Ground cable
- Antistatic mat
- BNC/RCA cables
- Fuses
- Cleaning alcohol
- Service checklist.

1.3.2 Special tools

In addition, the following special tools are required to service Elekta Neuromag:

- Vacuum pump and valve adapter (may be provided at the site)
- Helium level gauge calibration adapter (EL 20377T)
- Insert wiring tester (NM 20413K)
- EEG signal terminators
- EEG calibration adapter
- L-siphon adapter.
- Thermometer (measuring range 15-35 degrees of Celsius)
- Humidity meter (measuring range 5%-100%)

1.3.3 Tools available at site

At the site, make sure that there are the following tools:

- Spare part kit
- Phantom
- Nitrogen and helium gas cylinders and regulators
- Liquid helium for cooldown (100 liters + 100 liters)
- Cryogenic kit
- Vacuum cleaner for collecting dust from the electronics cabinets.

1.4 Overview of the system

The Elekta Neuromag measures non-invasively the magnetoecephalographic (MEG) and electroencephalographic (EEG) signals produced by electrically active tissue of the brain. These signals are recorded by a computerized data acquisition system, displayed, and may then be interpreted by trained physicians to help localize these active areas. The locations may then be correlated with anatomical information of the brain. MEG is routinely used to identify the locations of visual, auditory, somatosensory, and motor cortices in the brain when used in conjunction with evoked response averaging devices. MEG is also used to non-invasively locate regions of epileptic activity within the brain. The localization information provided by MEG may be used, in conjunction with other diagnostic data, in neurosurgical planning.

Elekta Neuromag® MEG channels are based on 306 superconducting thin-film sensors inside a cryogenic dewar vessel. The gantry, which supports the dewar, the patient bed, and the patient chair are operated inside a magnetically shielded room. For a block diagram overview of the system, see Figure 1.2. MEG electronics unit outside the magnetically shielded room reads out the sensor outputs through the filter unit, digitizes the signals, and controls the operation of the sensors. A data acquisition system collects and routes the data to the main computer system, as well as controls the electronics and data acquisition. For an example of the site layout, see Figure 1.3. For a schematic diagram of auxiliary electronics, see Figure A.5.

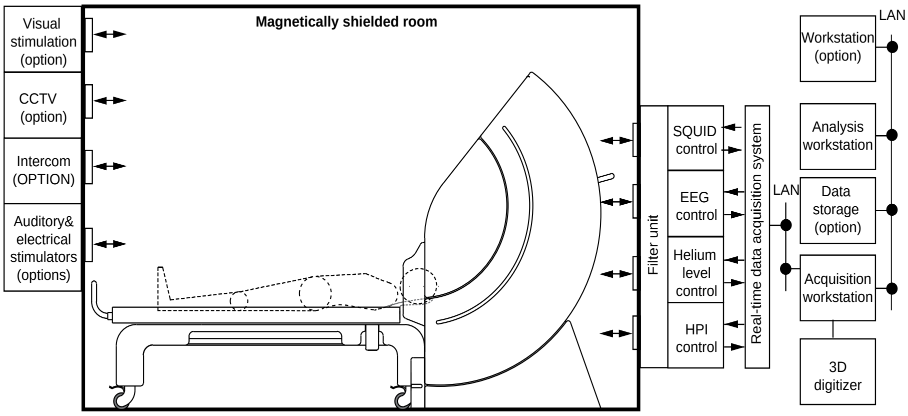

Figure 1.2 Block diagram overview of the system

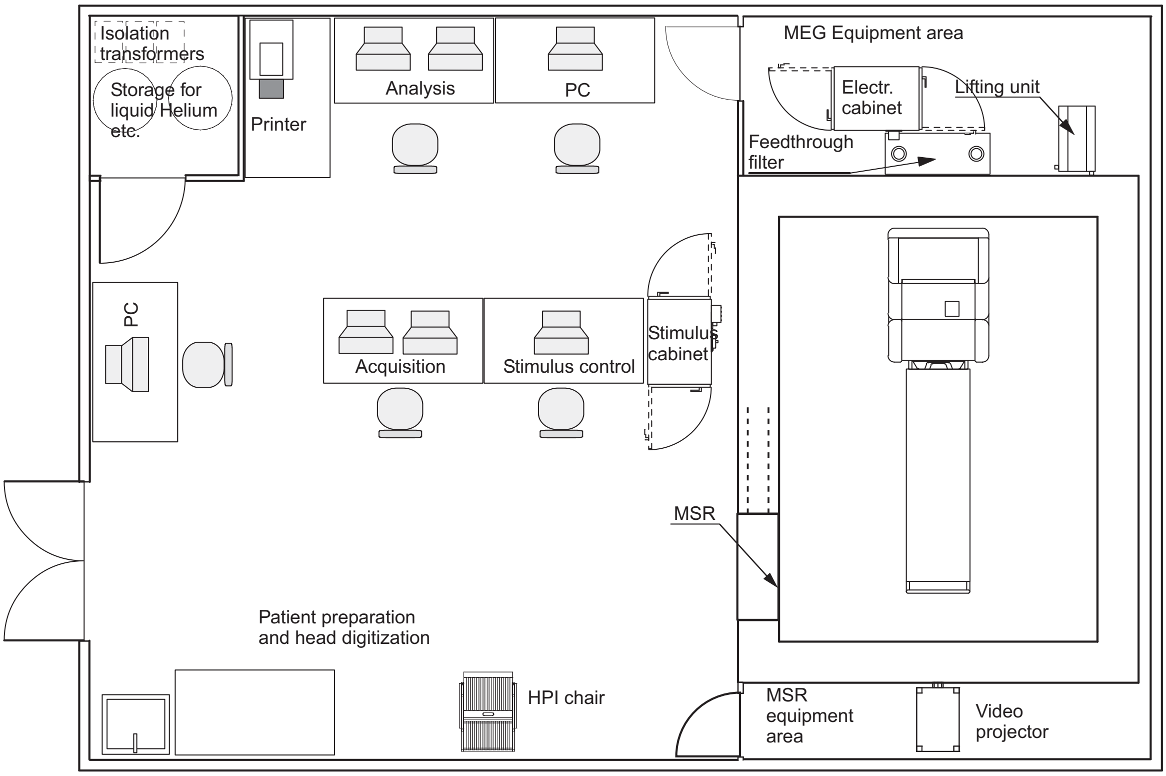

Figure 1.3 Example of the site layout

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CHAPTER 2 Hardware and Networking

2.1 Probe unit

2.1.1 Introduction

The core component of the Elekta Neuromag® system is the probe unit. It is located inside a magnetically shielded room (MSR) that reduces the environmental magnetic noise. The probe unit comprises a sensor insert with an array of 306 magnetic field sensors inside a cryogenic dewar and a supporting gantry, see Figure 2.1.

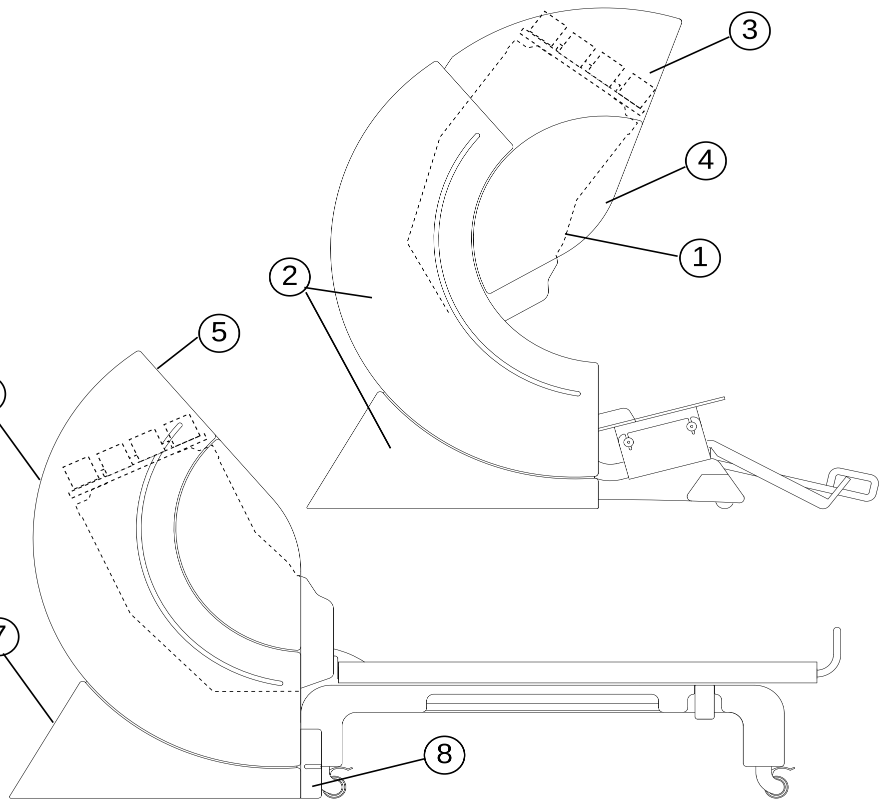


Figure 2.1 Probe unit

The probe unit consists of the following parts:

1. Dewar with a magnetometer insert containing 306 magnetic sensors and first-stage preamplifiers

2. Gantry base (stationary part)
3. Gantry cradle (moving part, holding the dewar)
4. Side panel
5. Removable hood for accessing the dewar top part and MEG preamplifiers
6. Removable back plate (screws under cover strips) for accessing the dewar top part and the MEG preamplifiers from back, the cabling, and the lifting mechanism secondary pulleys
7. Removable back hatch for accessing the EEG preamplifiers, the lifting mechanism main pulley, and the shaft
8. Removable docking piece for the bed.

The 306 sensors measure the magnetic field distribution around the head and convert it to 306 electrical signals. The sensors are immersed in liquid helium to keep their temperature stable at 4.2 K. At this temperature the sensors are superconducting. The 306-channel cryogenic insert contains 306 SQUID sensors positioned in a helmet-shaped array and the necessary support structures and cabling. The sensor insert is inside the cryogenic dewar.

The helmet-shaped cryogenic dewar is a vacuum-insulated vessel containing the liquid helium necessary for cooling the SQUID sensors to 4.2 K. It has a double-wall structure with a vacuum gap and an additional thermal radiation shielding in between. The neck plug of the probe unit also provides thermal insulation.

The supporting gantry is standing on the floor of the magnetically shielded room and it has a lifiting mechanism to move the dewar between two measurement positions: supine position for patients lying on a dedicated measurement bed and seated position for patients sitting on a special measurement chair. The dewar is mounted on a cradle moving along guide rails, driven by rope mechanism. The rope mechanism is powered by an electric motor located outside of the magnetically shielded room.

The hinged side panels hide a number of connectors used for connecting EEG electrodes, various auxiliary electronics parts, and a docking piece that is used to guide the patient bed to the right position. The docking piece is not used while measuring in the seated position. The gantry has also several removable hatches and covers to access the inside structures for service.

2.1.2 Sensor insert and the dewar

For the structure of the sensor insert inside the dewar, see Figure 2.2.

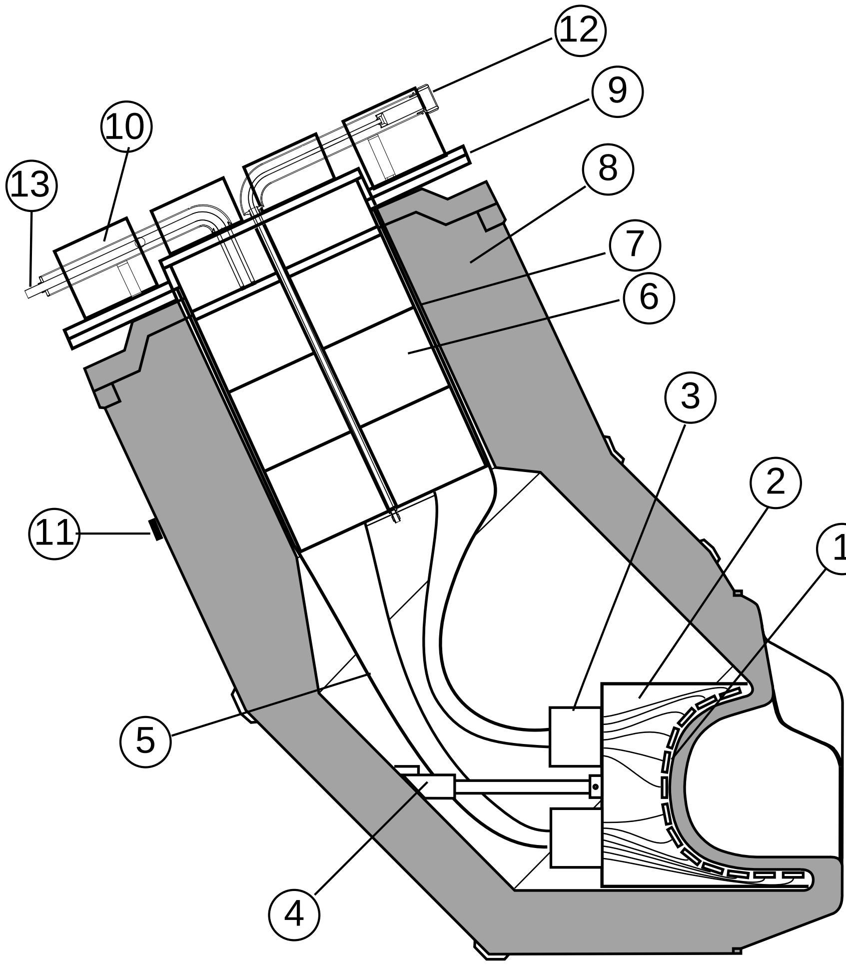


Figure 2.2 Dewar with the insert

There are the following parts in the dewar with the insert:

1. Helmet shaped detector array
2. Wiring unit
3. Sensor adapter boards
4. Wiring unit support rod
5. Neck cable assemblies
6. Neck plug
7. Dewar neck tube
8. Vacuum space with thermal radiation shields
9. Insert top flange with preamplifier motherboards
10. MEG preamplifiers
11. Vacuum pump-out port
12. L-siphon
13. Helium gas exhaust tube.

The detector array comprises a helmet-shaped support shell equipped with sensor sockets into which the triple sensor elements (each having three channels) are plugged in. Each sensor socket has two connectors. The sensor socket is mounted on a flexible planar spring. There are 102 sensor sockets.

The wiring unit (see Figure 2.3 and Figure 2.5) consists of a helmet-shaped support for the elastically mounted sensor sockets, wiring from sensor sockets to sensor adaptor boards, sensor adapter boards, and a protective shell (also acting as a spring). The protective shell has a sealing ring (see Figure 2.4) to prevent eventual solidified oxygen from entering near the sensors. The support rod locks the wiring unit firmly on its place to prevent mechanical vibrations of the sensor array. A liquid helium level probe is also mounted on the wiring unit (see Figure 2.5).

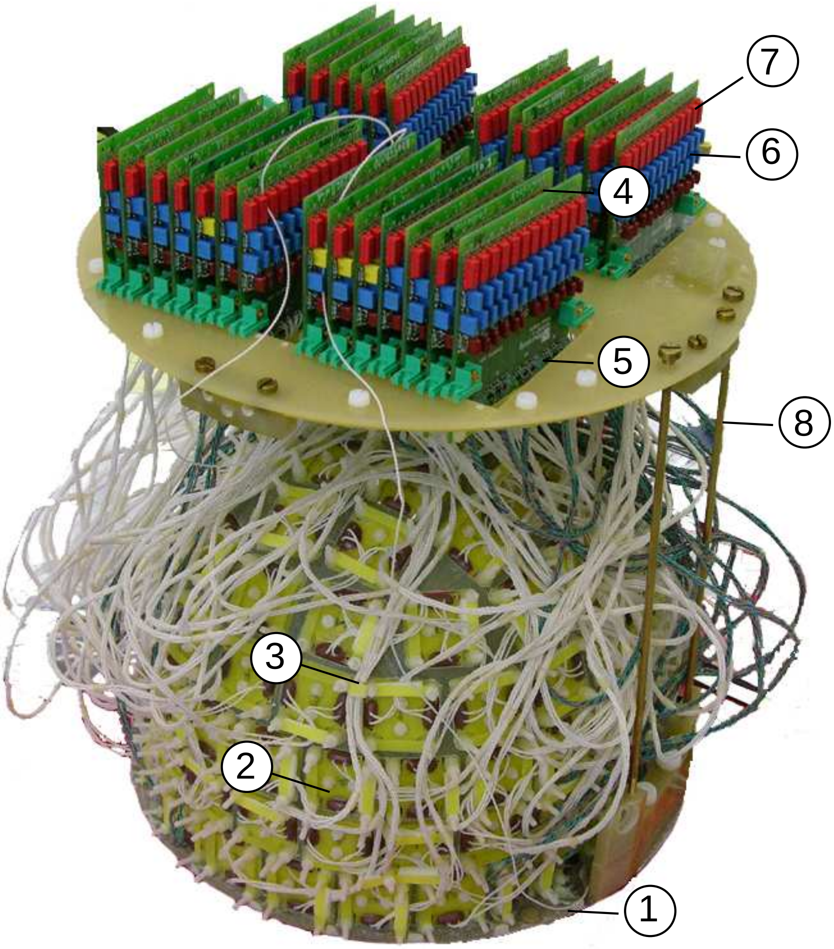


Figure 2.3 Wiring unit

The photograph above has been taken during installation without the protective shell. The assembly of cable bundles and ties is only partial. The wiring unit consists of the following parts:

1. Helmet-shaped support
2. Sensor socket assembly, mounted flexibly on the helmet-shaped support

3. Wiring from sensor sockets to sensor adapter boards (tied to helmet-shaped shell and bundled together in normal use)
4. Sensor adapter boards
5. Field effect transistors (FETs) for amplifier noise cancellation (normally not visible as they are below the wiring unit top plate)
6. Passive filtering components
7. Connectors to the neck cable assembly
8. Support rods (used only during installation and removed after installation).

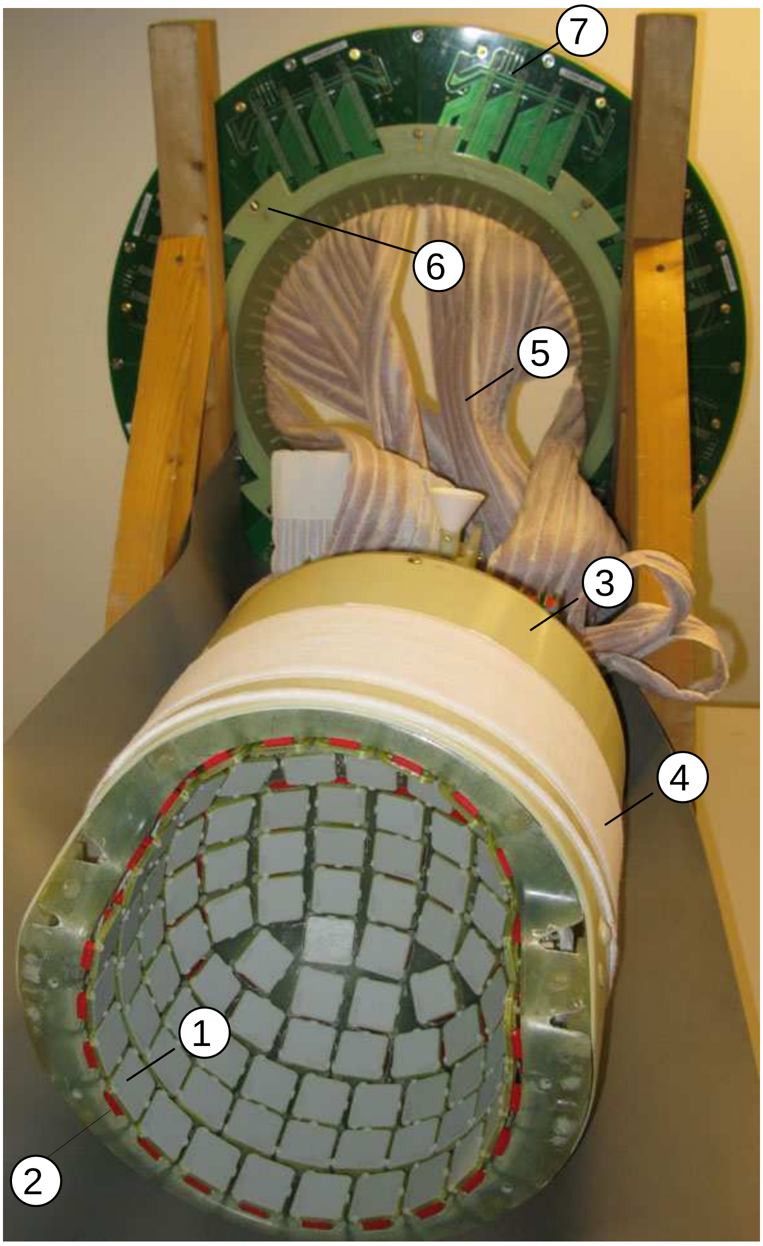


Figure 2.4 Sensor insert

There are the following parts in the sensor insert:

1. Triple sensor elements

2. Sensor element connectors
3. Wiring unit shell
4. Sealing ring
5. Textile support for cable bundles
6. Support ring
7. Preamplifier motherboards, made of eight sectors (“octants”).

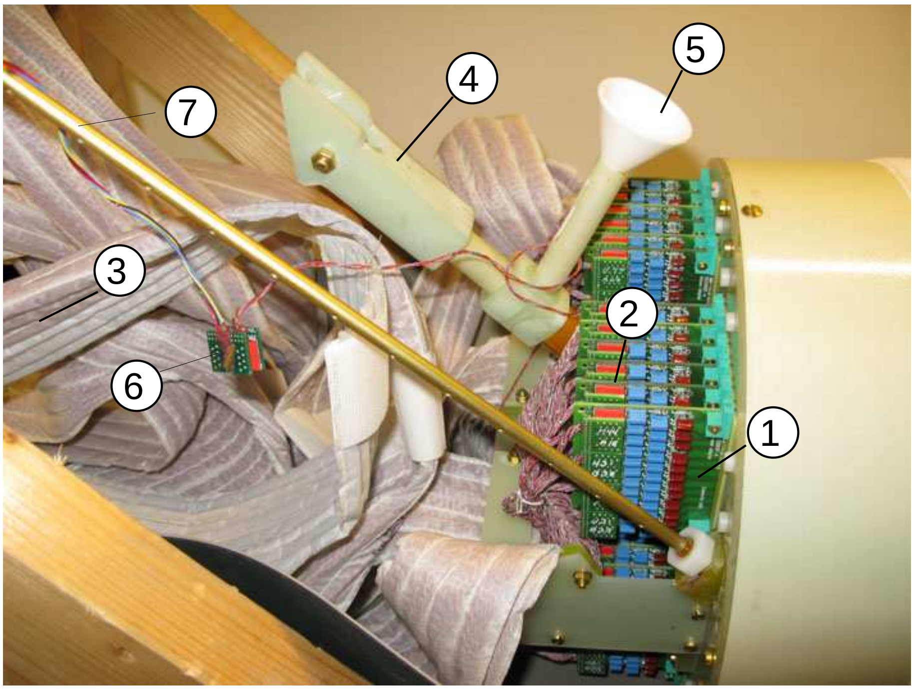


Figure 2.5 Middle section of the insert

The middle section of the insert consists of the following parts:

1. Sensor adapter boards
2. Neck cable connectors
3. Neck cable assemblies inside textile supports
4. Wiring unit support rod
5. Funnel to match the end of the L-siphon extension during cooldown (to direct the helium stream to the lowest parts of the insert)
6. Connector for the liquid helium level probe
7. Liquid helium level probe.

The sensor adapter boards (see Figure 2.3 and Figure 2.5) contain the feedback resistors, passive radio frequency (RF) filtering components, and the field effect transistors (FETs) for the amplifier noise cancellation. Each sensor adapter is connected to four sensor sockets. Therefore, each sensor adapter has 12 channels. There are 26 sensor adapter boards plus one auxiliary board for the liquid helium level sensor and the thermometer resistors. Each sensor adapter board connects to a corresponding preamplifier (also 12 channels).

The cable assemblies connecting the room-temperature parts and the sensor adapter boards (see Figure 2.4) are made of resistive wires to minimize thermal conduction from room temperature to the liquid helium bath. The cables are mounted inside textile supports and they run from the sensor adapter boards to the insert top flange.

The dewar is made of inner and outer shells, tied together only at the top plate and separated by a vacuum space. The vacuum space is also equipped with thermal radiation shields and a so-called super-insulation which is made of multiple layers of plastic foil coated with a thin layer of aluminium. A pump-out port with a vacuum valve is located at the back of the dewar. A special adapter is needed to operate the valve and to connect the vacuum pump.

The neck plug provides thermal insulation and directs helium gas boiling off the liquid helium bath to flow along the dewar neck tube. When the flow is forced along the neck tube wall the heat conduction along the tube wall is effectively reduced. Moreover, the thermal radiation shields are thermally anchored to the neck tube to keep them at a lower temperature. The cable assemblies are also mounted in the space between the neck plug and the neck tube to reduce thermal conduction. A helium exhaust tube is mounted on the neck plug, collecting the outflowing gas and directing it out.

The insert top flange (see Figure 2.6) contains support plates and preamplifier motherboards. The motherboards, made of eight octant sectors make a gas-tight signal feed-through to the helium space. The preamplifiers mounted in the corresponding slots on the preamplifer motherboard read out and amplify the signals from the sensor elements and control the setting of the operating point.

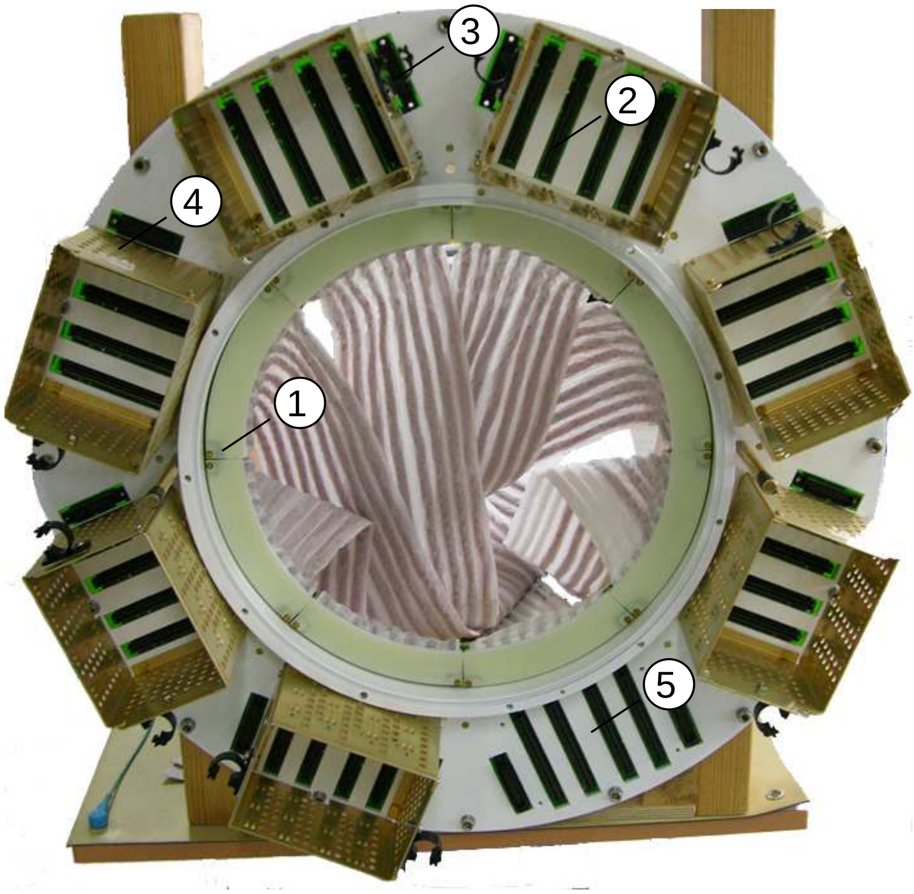


Figure 2.6 Preamplifier top flange

The preamplifier top flange consists of the following parts:

1. Neck cable assembly connectors under the protective cover acting also as a strain relief
2. Preamplifier connector
3. Power and digital control cable connector
4. Support cage for preamplifiers
5. Dummy motherboard (octant 8).
   There is a dummy textile support assembly connected to octant 8 to keep the helium flow evenly distributed.

Each preamplifier motherboard octant has four slots per board. Each slot in the system has a unique address consisting of the board number + slot number (address numbering starting from 0). Each board number has been set at factory by soldering jumpers on address pads, and the address of each slot has been hard-wired on the PCB. Each octant has 2 x D25 connectors, one for the power/control cable, one for the terminator. The control cable can be connected to either of the two D25 connectors associated with every motherboard octant, and the remaining D25 connector must be terminated with a data terminator block (see Figure 2.7 and Figure 2.8).

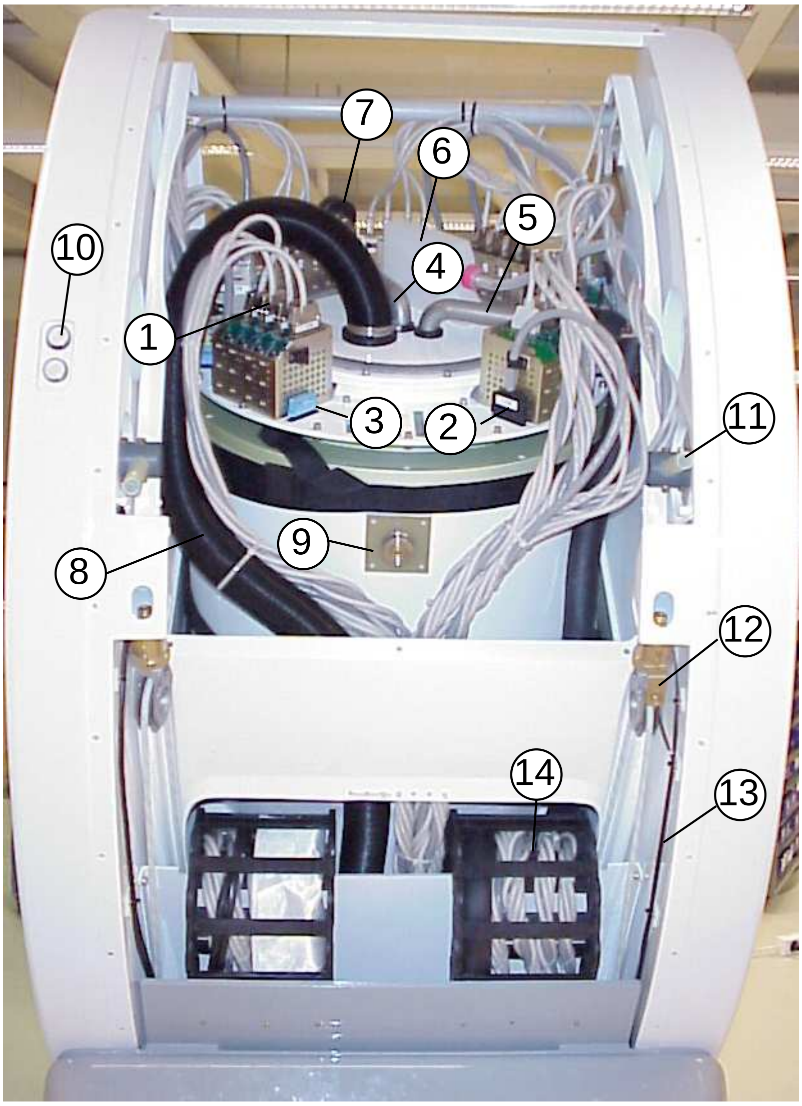


Figure 2.7 Gantry seen from the back

In the figure above the covers have been removed. There are the following parts in the gantry seen from the back:

1. Preamplifier signal cables
2. Preamplifier control and power cable
3. Control data terminator
4. L-siphon (equipped with a pressure relief valve)
5. Helium gas exhaust tube (vacuum-insulated)
6. Pressure ballast
7. Pressure gauge
8. Safety exhaust duct
9. Vacuum pumpout port
10. Lifting mechanism actuating buttons
11. Lifting mechanism safety latch release lever
12. Lifting mechanism secondary rope pulley

13. Optical fiber for the lifting mechanism position sensors
14. Cable support chain to lead the cables from the moving dewar cradle to the gantry base.

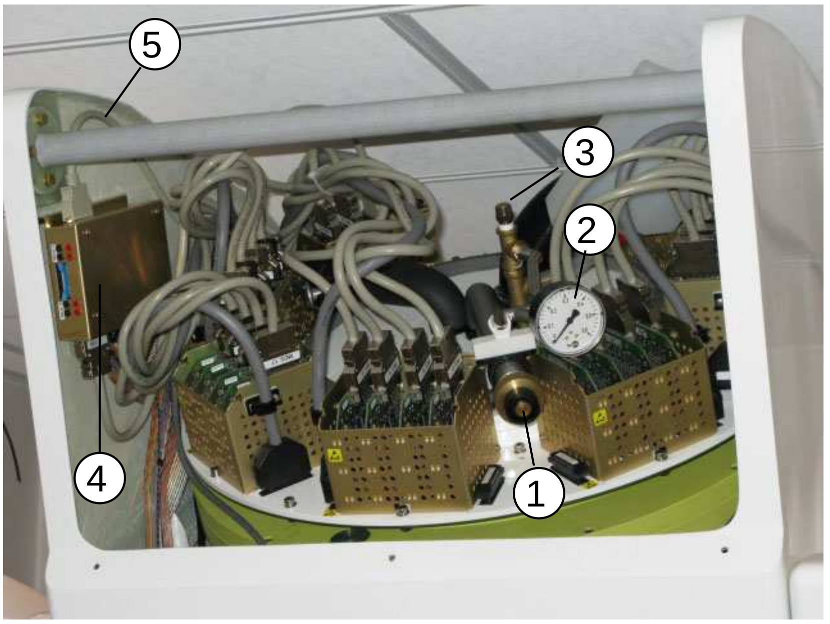


Figure 2.8 Gantry top seen from the front

In the figure above the hood has been removed. There are the following parts in the gantry seen from the front:

1. L-siphon plug with the pressure relief valve
2. Pressure gauge
3. Pressure relief valve
4. Liquid helium level gauge unit
5. Control and power cable to the liquid helium level gauge unit.

The L-siphon is a vacuum-insulated tube leading from the top flange to the lower side of the neck plug for transferring liquid helium into the dewar. The L-siphon connects to a flexible siphon used for transferring liquid helium from a storage container. During the cool-down of the system the L-siphon is equipped with an extension piece (not shown in the figures) which guides the initial cold helium flow to the lower parts of the dewar. During normal use, the extension tube must be removed and replaced by a short particle filter.

2.1.3 Liquid and gaseous helium

A siphon is used for transferring liquid helium from a storage container to the dewar when a refill is needed, see Figure 2.9. It is a flexible, vacuum-insulated doublewall tube.

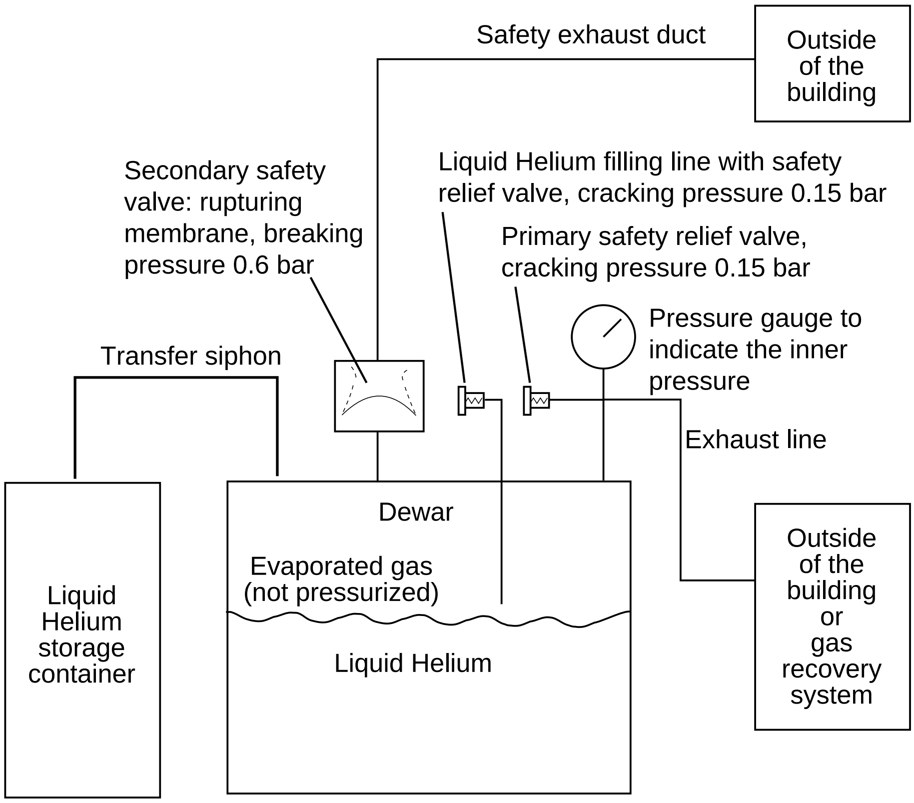


Figure 2.9 Liquid and gaseous helium systems

Helium gas evaporating from the dewar is routed typically via a special exhaust system to the outside air or to a gas-recovery system (if available). The primary safety pressure relief valve prevents build-up of pressure, if, for instance, the exhaust line gets blocked. In addition, the liquid helium filling line leading to the liquid helium space is equipped with a pressure relief valve to provide an independent way of preventing pressure build-up, if, for instance, the dewar neck parts get blocked. If there is a sudden loss of vacuum, helium evaporates abruptly, which makes the pressure rise rapidly and the relief capacity of the primary valve exceed. Consequently, the rupturing membrane acting as a secondary safety valve gets broken. This results in letting the gas escape via the safety duct to the outside of the building. A pressure gauge on top of the dewar shows the internal pressure. At normal pressure the dewar inner parts are virtually at athmospheric pressure; however, during cooldown, warmup, or liquid helium fill-up the pressure may rise because of rapid evaporation of helium.

For the inner parts of the dewar, see Figure 2.7 and Figure 2.8. To prevent thermo-acoustic oscillations (also known as Tachonics oscillations) in the exhaust line, which could lead to markedly increased liquid helium boil-off, the exhaust line is equipped with a pressure ballast.

At some sites the exhaust system may contain an external helium boil-off valve unit. It is used for connecting the dewar exhaust hose and storage dewar exhaust hose to a helium boil-off feed-through tube that is connected to a check-valve. This is may be connected via a heat exchanger to a gas meter (if installed).

2.1.4 Lifting mechanism

The dewar cradle is moved between the supine and seated positions by using a rope mechanism. The pulley connected to the main shaft is powered by a motor outside the room driving the primary rope. A secondary rope connected to the dewar cradle winds or unwinds from the main shaft as the cradle moves. The pulley-shaft combination provides gearing to reduce the tension of the primary rope. The secondary rope forms a loop firmly attached at the middle to the cradle, effectively forming two independent secondary ropes. At the measurement positions the weight of the cradle is resting on end stoppers (supine position) or on two safety latches (seated position) so that at secured measurement position there is no tension on the ropes at all. The latches are automaticlly engaged by a spring when the hole in the cradle passes by the latch. To monitor the status and to indicate a safe measurement position, the system has been equipped with four optical fibre sensors, control electronics and an indicator display on the wall of the magnetically shielded room. The detectors (based on sensing a refelection from a surface) sense the dewar uppermost and lowermost positions, the latch engagement and the secondary rope tension.

For the lifting mechanism, see Figure 2.10. For details of the lifting mechanism, see Figure 2.7, Figure 2.8, Figure 2.11, and Figure 2.12.

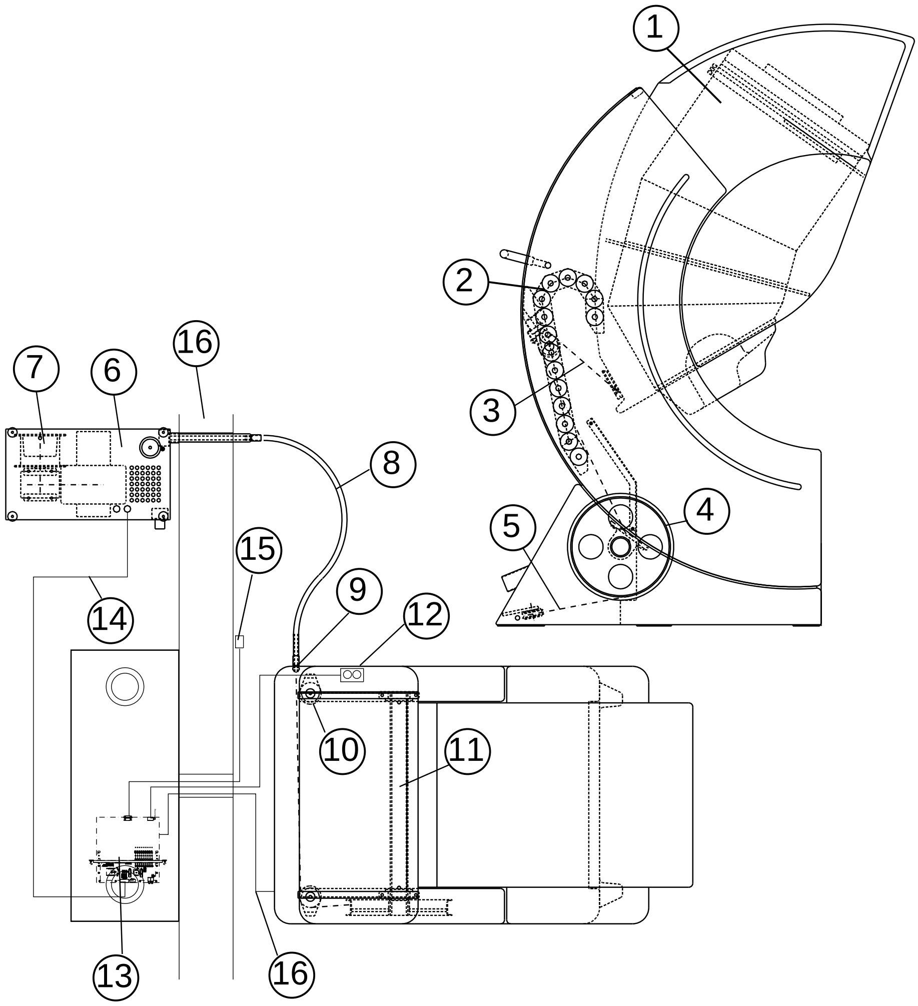


Figure 2.10 Lifting mechanism

The lifting mechanism consists of the following parts:

1. Dewar cradle, moving on wheels along rails inside the gantry base
2. Cable support chain
3. Secondary rope
4. Pulley for the primary rope
5. Primary rope
6. Lifting motor unit with separate mains power
7. Drum for the primary rope, driven by the motor
8. Bowden cable
9. Entry point for the Bowden cable (alernatively on the right side)
10. Additional pulley if the Bowden cable is entering from the right side
11. Main shaft
12. Push buttons to control the movement
13. Movement control unit inside the feed-through filter cabinet
14. Motor control cable
15. Position indicator display of the lifting mechanism

16. Optical fibers of the position indicator sensor in the lifting mechanism.

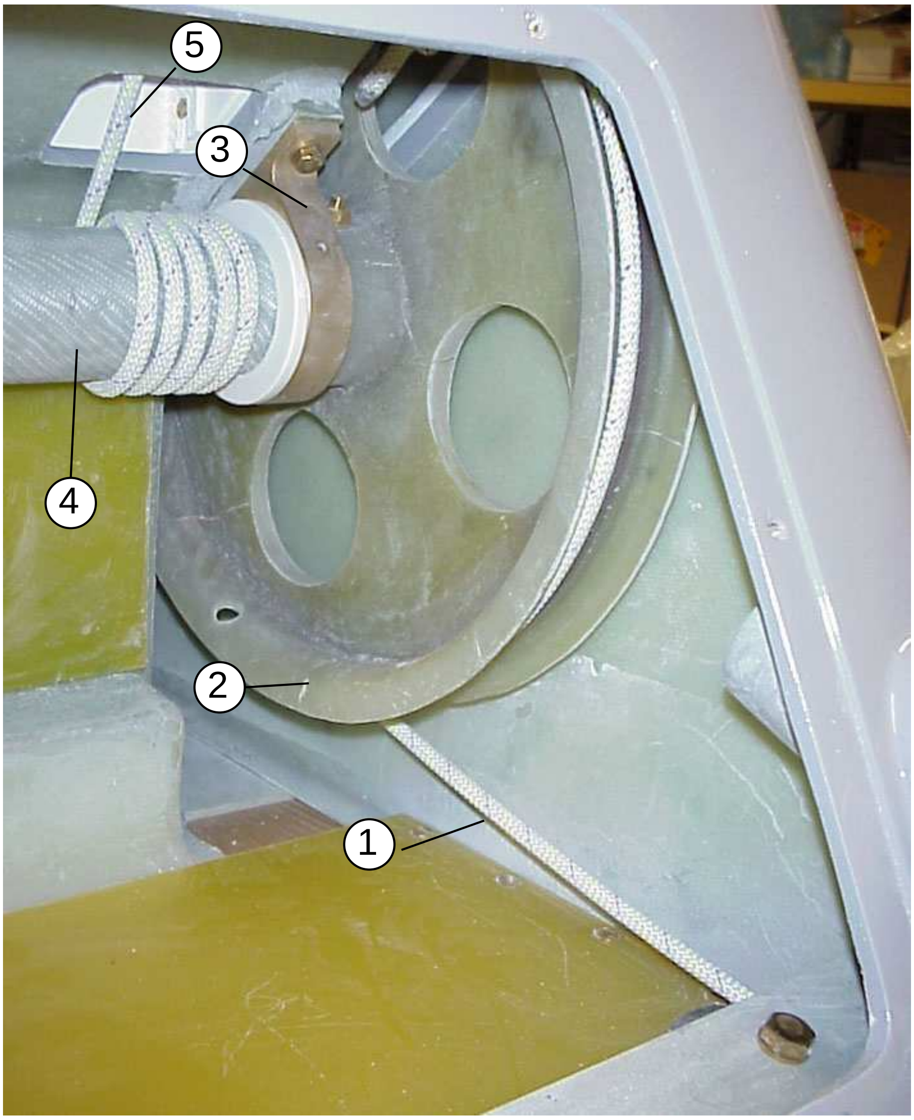


Figure 2.11 Lifting ropes inside the lower back parts of the gantry

The following are shown in the back part of the gantry:

1. Primary rope
2. Primary rope pulley
3. Bearing for the main shaft
4. Main shaft
5. Secondary rope.

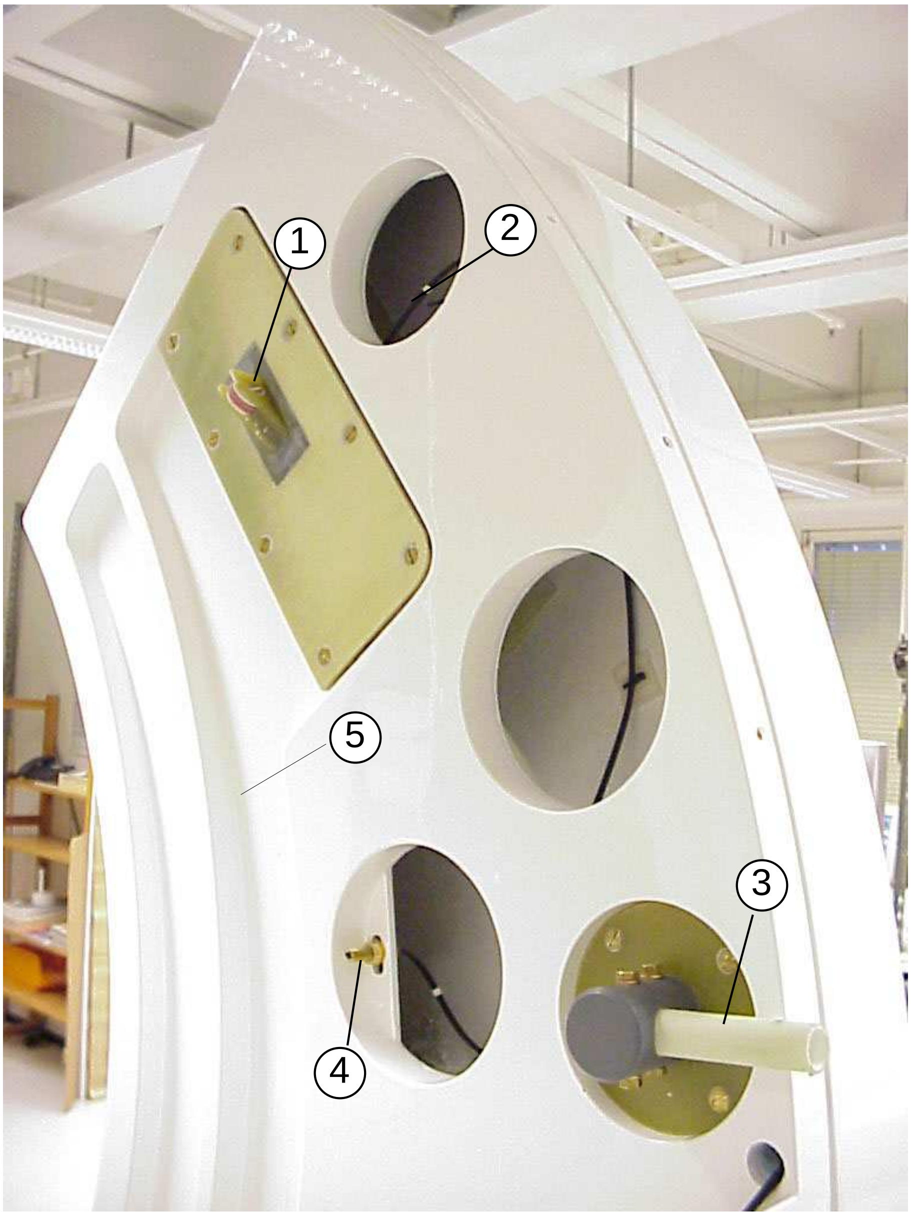


Figure 2.12 Safety latches and fiber sensors

The dewar cradle has been removed in the figure above. There are the following safety latches and fiber sensors:

1. Safety latch
2. Sensor fibers of the safety latch
3. Lever for releasing the latch
4. Sensor fiber detector
5. Guide rails for the cradle wheels.

2.2 Electronics

2.2.1 Main electronics cabinet

The main electronics cabinet comprises two MEG subracks, one EEG subrack and an MEG preamplifier power supply, see Figure 2.13. For a schematic diagram of the electronics, see Figure A.1. For a block diagram of the electronics, see Figure 2.14.

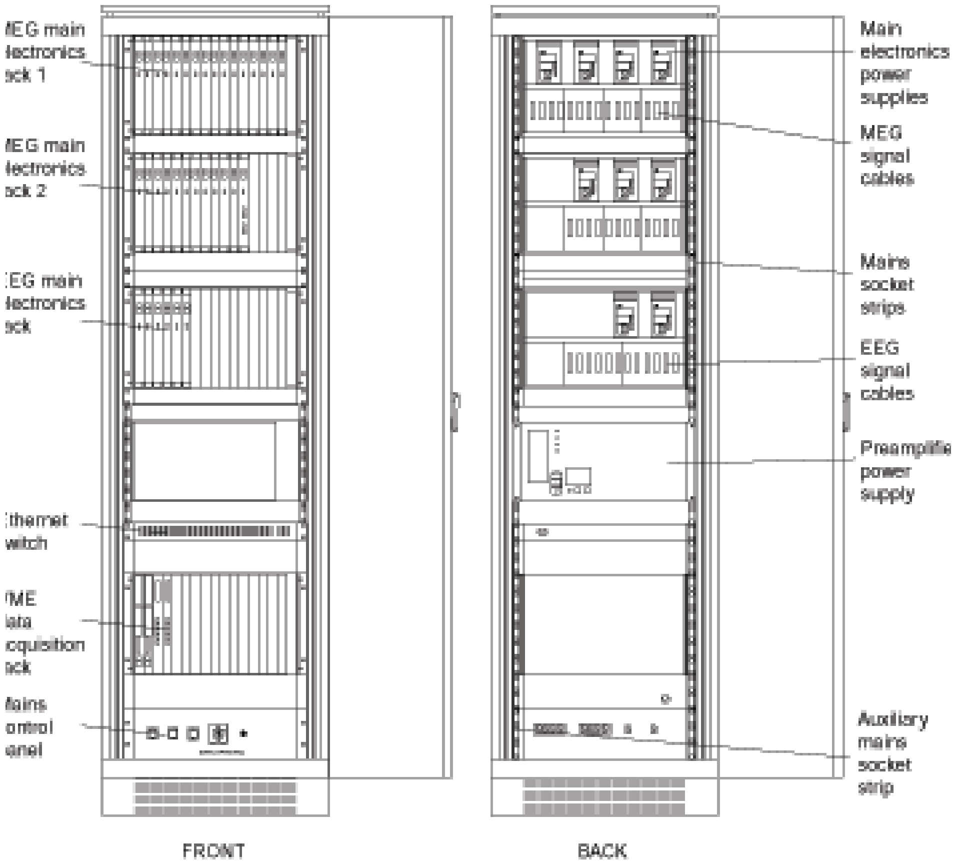


Figure 2.13 Mounting of the electronics units inside the main electronics cabinet. Left: front view, right: back view

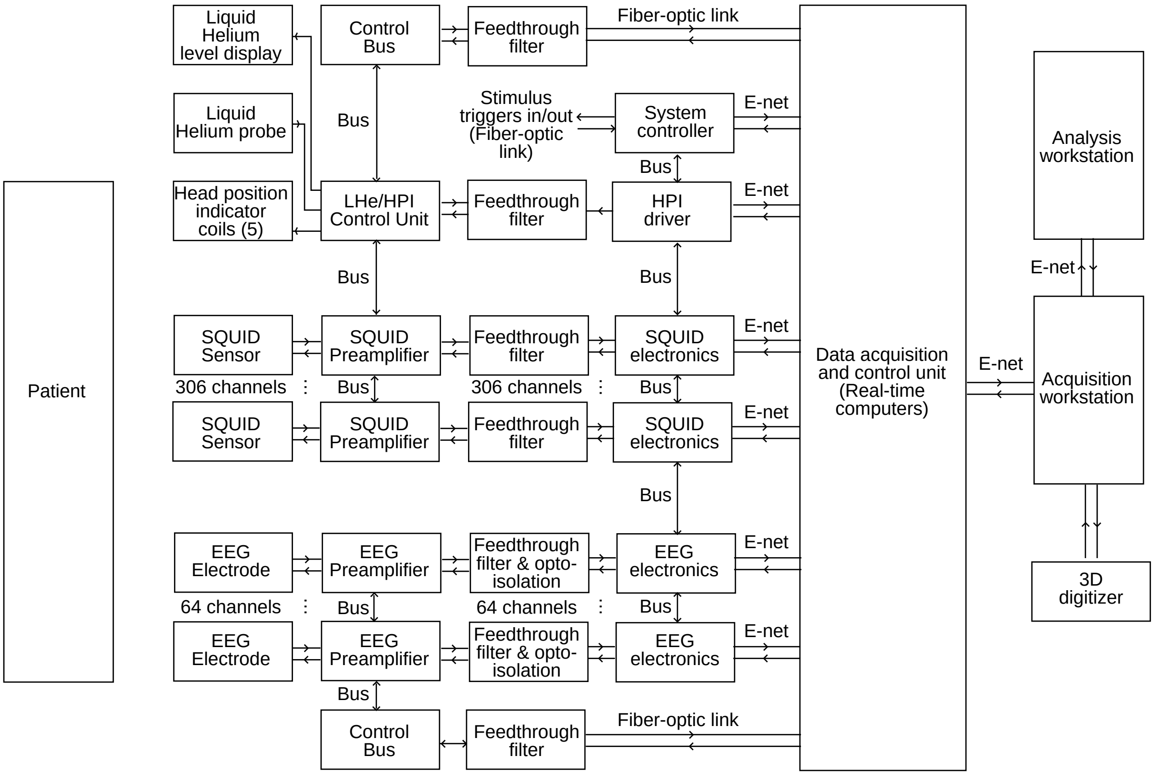


Figure 2.14 Block diagram of the electronics

2.2.2 MEG electronics

For the MEG electronics components, see Figure 2.15. The MEG electronics can be divided in the following blocks:

- Preamplifiers inside the probe unit
- Feed-through RF filters inside the filter unit
- Control/power feed-through filter inside the filter unit
- Main electronics racks and real-time data acquisition computers in the VME rack inside the main elecronics cabinet.

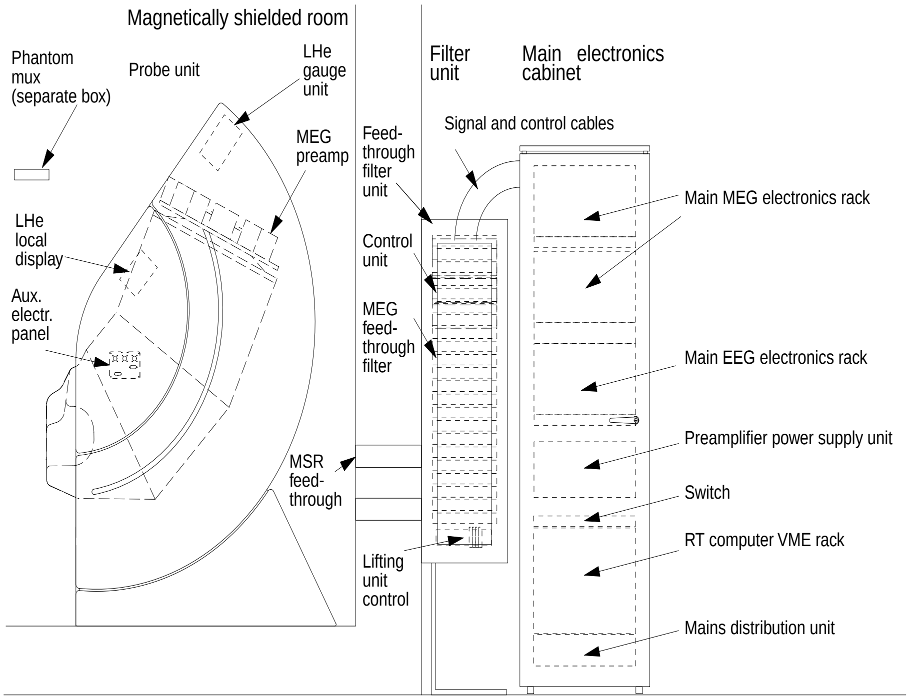


Figure 2.15 MEG electronics components

2.2.3 EEG electronics

For the EEG electronics components, see Figure 2.16. For a block diagram of the EEG electronics, see Figure 2.17. For a schematic diagram of the EEG electronics, see Figure A.2. The EEG system comprises 64 channels, optionally expandable to 128 channels. The electronics is divided into the following blocks:

- Preamplifier unit inside the probe unit, including built-in electrode interface
- Opto-isolation/feed-through filter inside the filter unit
- Isolated power supply inside the filter unit
- Control/non-isolated power feed-through filter inside the filter unit
- EEG main electronics rack in the main electronics cabinet (MEG electronics use the same data acquisition computers).

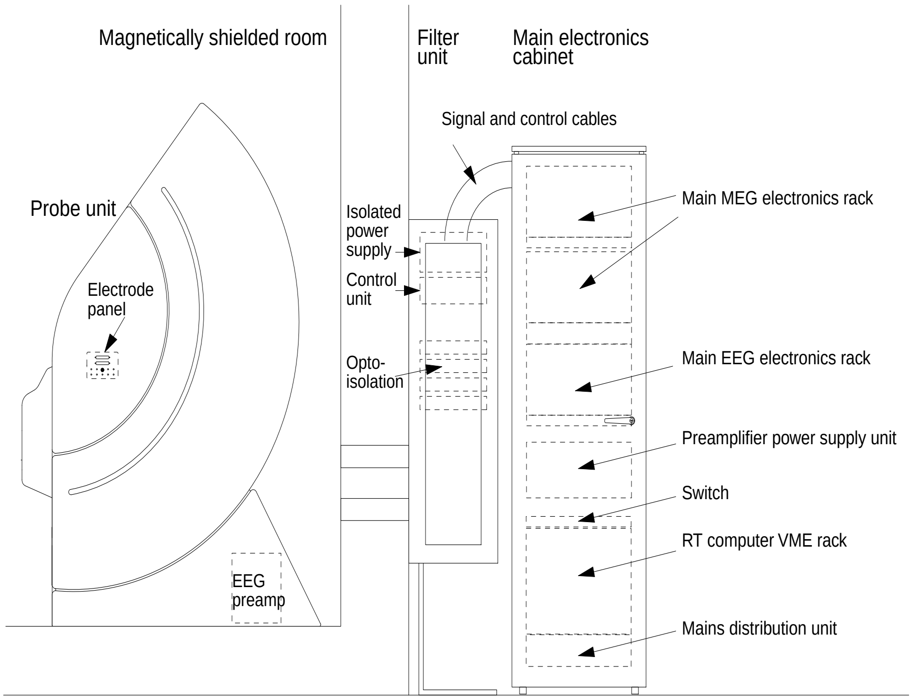


Figure 2.16 EEG electronics components

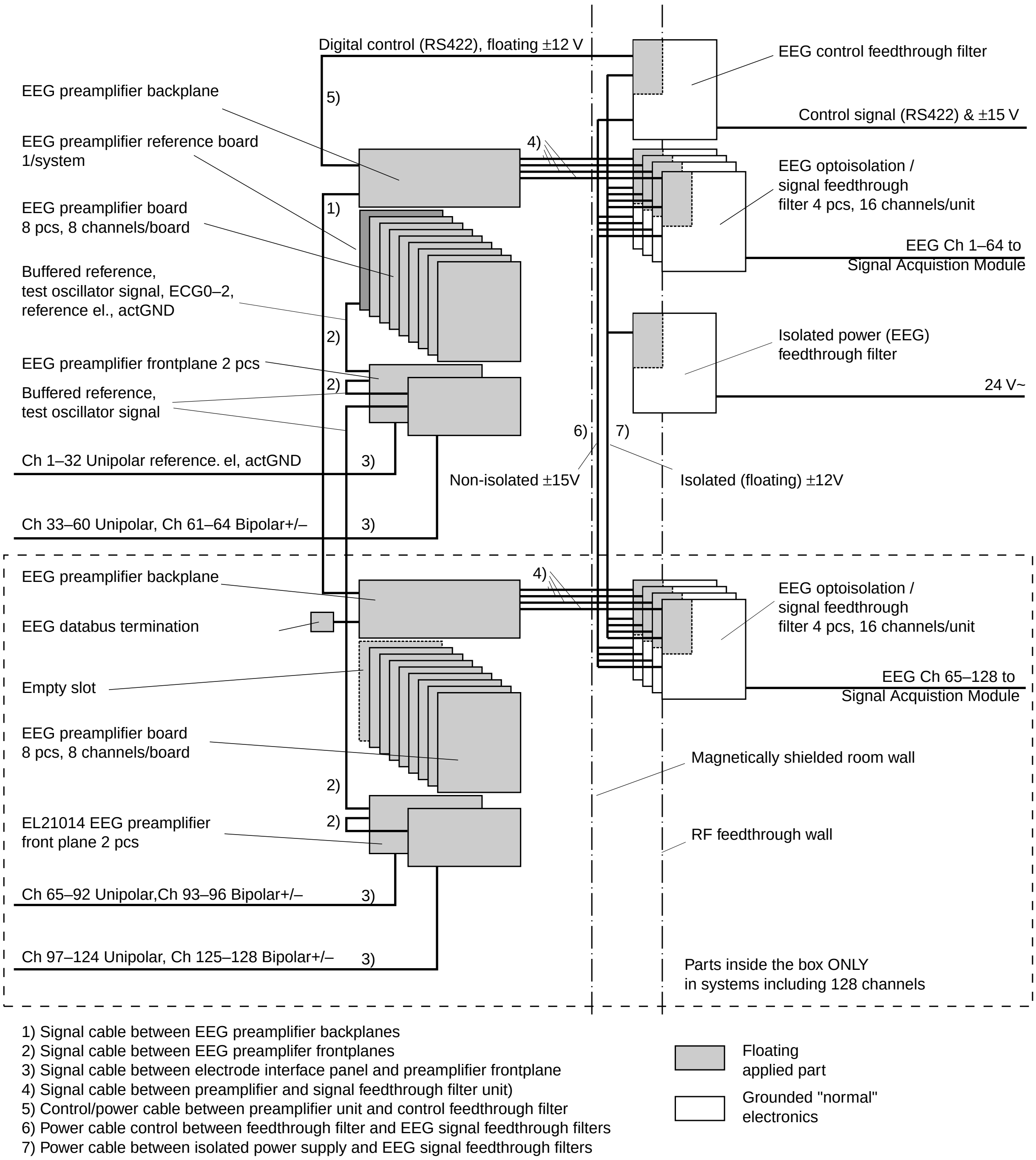


Figure 2.17 Block diagram of the EEG electronics

2.3 Auxiliary hardware modules

2.3.1 Phantom

A phantom is provided for checking the system performance, see Figure 2.18. It contains 32 artificial dipoles and four fixed head-position-indicator coils. The phantom is based on the mathematical fact that an equilateral triangular line current produces equivalent magnetic field distribution to that of a tangential current dipole in a spherical conductor, provided that the vertex of the triangle and the origin of the conducting sphere coincide. The phantom dipoles are energized using an internal signal generator which also feeds the HPI coils. An external multiplexer box is used to connect the signal to the individual dipoles. Only one dipole can be activated at a time.

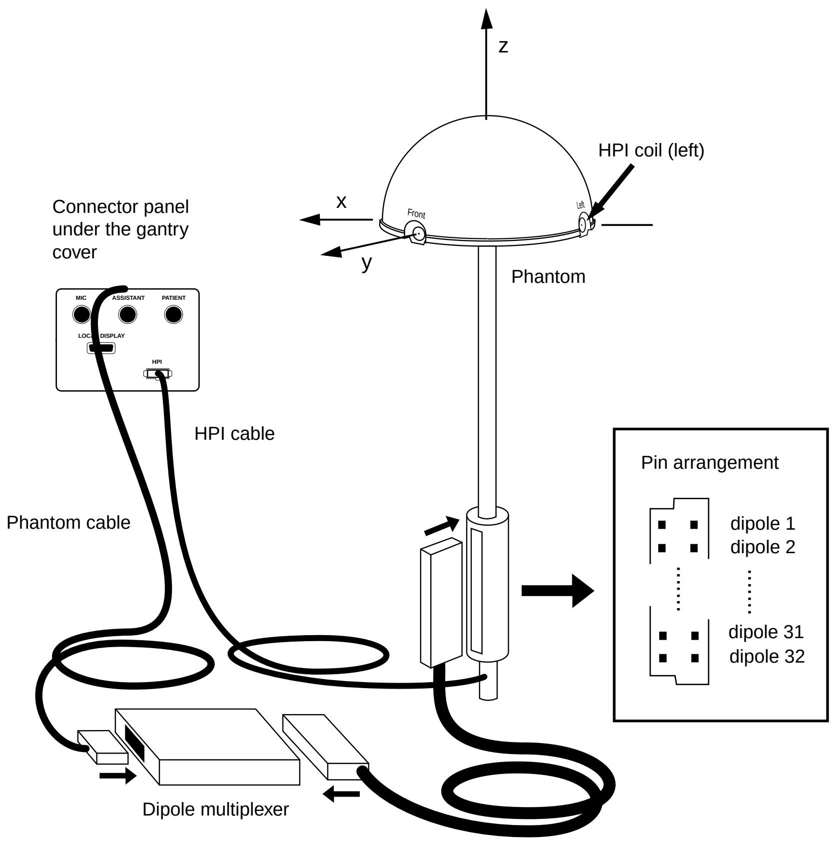


Figure 2.18 Phantom

2.3.2 HPI and 3D digitizer

The head position indicator (HPI) system is based on coils placed on known locations on the head, see Figure 2.19. A single coil can be energized by a coil driver card with currents of different frequencies. The excitation signal is provided by the data acquisition system. A three-dimensional Fastrak digitizer (manufacturer: Polhemus, Inc, USA) is connected to the computer system, see Figure 2.20. It is used in the preparation phase before MEG measurement to digitize the positions of the head position indicator coils as well as the landmarks on the head which are visible in the MRI scan.

Figure 2.19 HPI coils

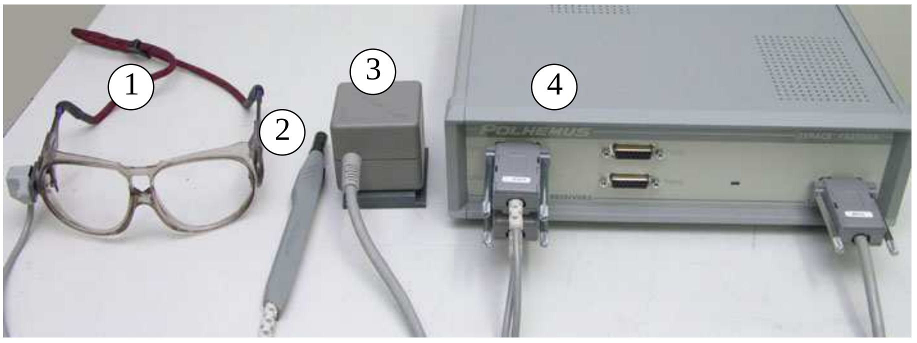


Figure 2.20 3D digitizer unit

3D digitizing requires the following devices (see Figure 2.20):

1. Goggles with a separate reference receiver (goggles to receiver 2)
2. Digitizing stylus pen (pen to receiver 1)
3. Transmitter coil
4. 3D-digitizer unit.

2.3.3 Voice intercom system

The voice intercom system has been designed not to cause any interference to the Elekta Neuromag®. However, to avoid disturbances, the microphone should be kept further than 30 cm away from the helmet.

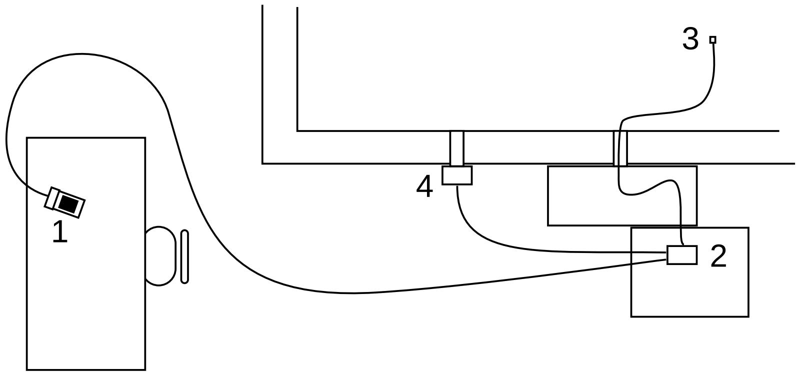


Figure 2.21 Intercom system

The voice intercom system is composed of a table station (1) and a main station with a power supply (2), see Figure 2.21. The microphone (3) of the main station is inside the magnetically shielded room. The microphone cable runs to the main station via the feed-through filter. The loudspeaker for the main station is outside of the magnetically shielded room attached on a separate feed-through tube on the magnetically shielded room wall (4).

2.3.4 Video monitoring system (optional)

For a schematic diagram of the closed-circuit television system, see Figure 2.22.

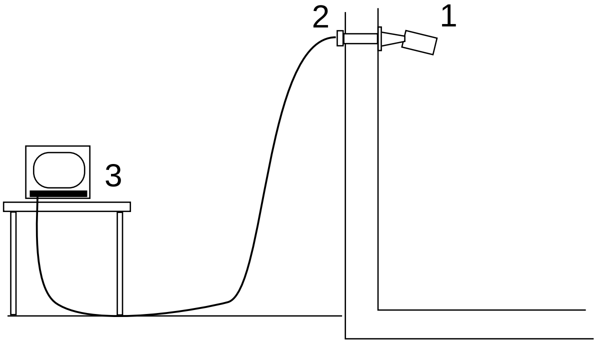


Figure 2.22 Video monitoring system

The camera (1) is placed inside a separate RF shield. The cable (2) goes through a dedicated feed-through to the monitor (3). The camera should be kept further than one meter away from the Elekta Neuromag® to avoid additional noise.

2.3.5 Stim systems (optional)

A 16-channel trigger pulse (digital) input-output interface is provided for synchronizing the measurement software and stimulators (not supplied with the standard system) used for evoked-response studies. The interface unit is optically isolated from the main electronics and data acquisition system.

The RF-shielded stimulus electronics cabinet is used to prevent possible RF disturbances caused by stimulus devices from entering the magnetically shielded room. RF-filtered feed-throughs are available between the inside and the outside of the cabinet. Active digital circuitry, for example a computer inside the stimulus cabinet should be avoided.

2.4 Workstation hardware

The standard system configuration typically includes two UNIX workstations: one for performing and controlling measurements and on-line processing (acquisition workstation) and the other for off-line analysis of data (analysis workstation). Additional mass storage and output devices can be added to the system according to need.

2.5 Networking

For an overview of the network, see Figure 2.23.

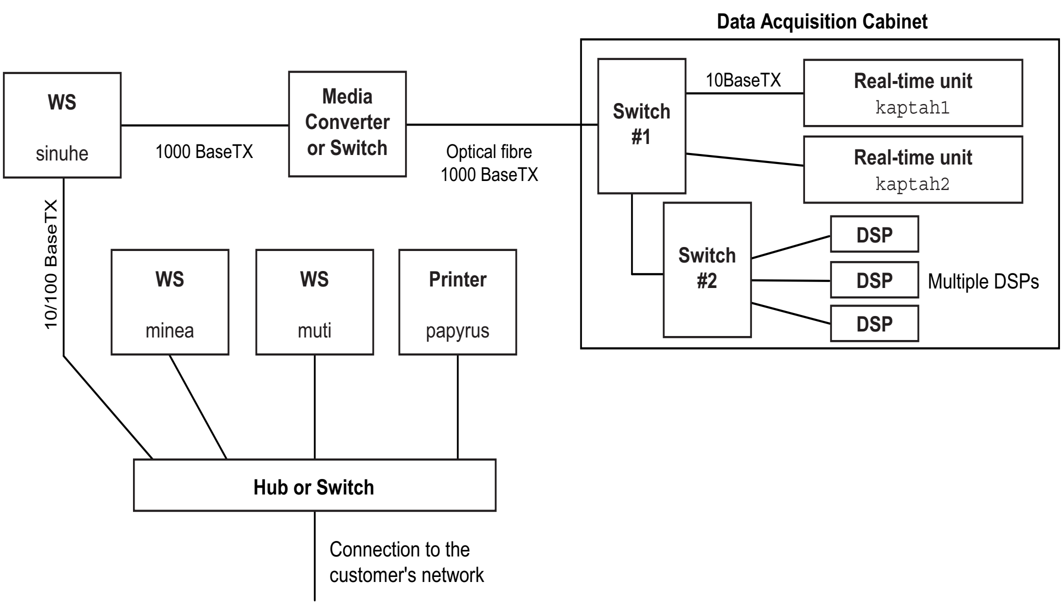


Figure 2.23 Overview of the network

- Acquisition workstation network host name is `sinuhe`.
- Analysis workstation network host names are `minea` and `muti`.
- Workstation IP addresses are site-dependant.
- Real-time unit (RT) network host names are `kaptah1` and `kaptah2`.
- Dedicated RT IP network addresses are 192.168.100.11 and 192.168.100.12.
- RT units run the *collector* server to collect the measured signals as well as the *janitor* server to control the MEG preamplifiers and the *janitor_eeg* server to control the EEG preamplifiers. `kaptah1` runs the *janitor* server. `kaptah2` runs the *janitor_eeg* server.
- All application software and configuration files are loaded from the acquisition workstation during boot-up.

3

CHAPTER 3 Software

3.1 Data acquisition software

For a data acquisition software block diagram, see Figure 3.1

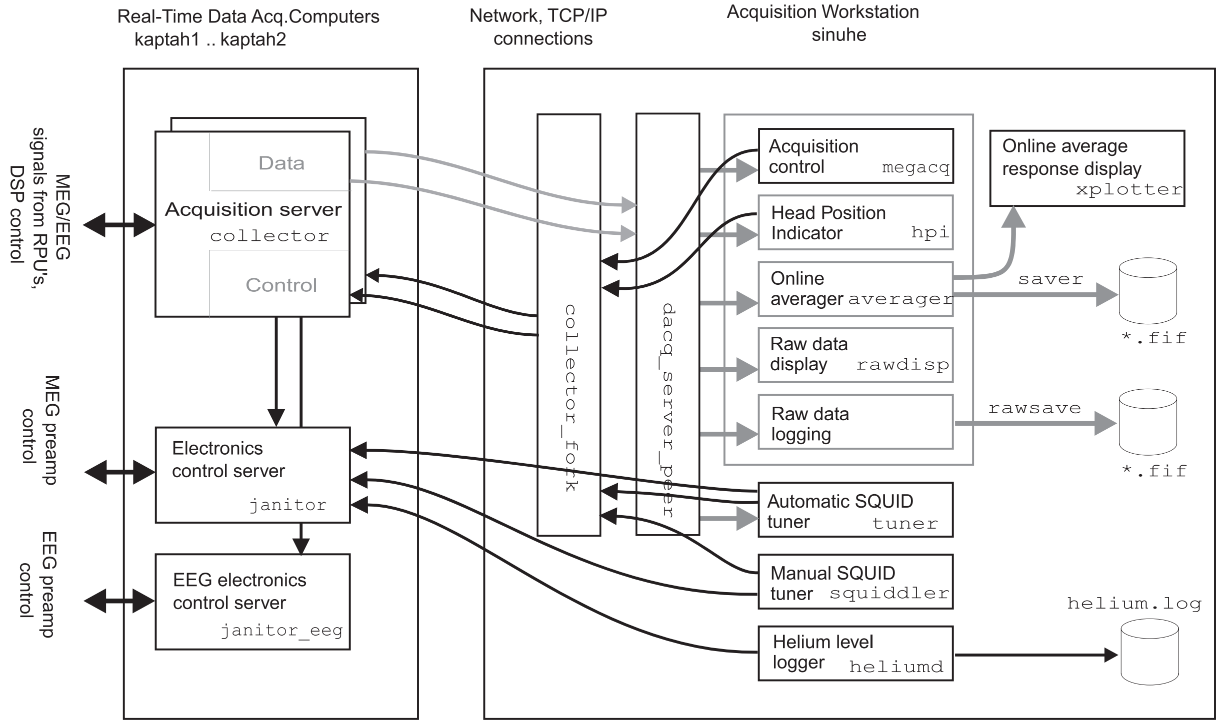


Figure 3.1 Data acquisition software block diagram

3.1.1 Neuromag directory tree

Neuromag root directory

- `/neuro` -- the root directory of the Neuromag tree and a symbolic link to `/net/sinuhe/opt/neuromag` created on every workstaion.
- `/opt/neuromag` -- Neuromag software is physically installed under this directory on one or all of the workstations.

MEG/MRI data areas

- `/neuro/data` -- the main data storage. Usually this a symbolic link pointing to another file system.
- `/neuro/mri` -- storage for MR-images. This may also be a symbolic link to another file system.
- `/neuro/databases` -- subject and project databases as well as the list of data volumes (in the `volumes` file).

Programs

- `/neuro/bin/vue` -- scripts connected to the MEG toolbox icons. These scripts first set up the environment correctly for the analysis programs and launch them.
- `/neuro/bin/X11` -- binaries of the graphical analysis programs. Do not start them directly.
- `/neuro/bin/util` -- various non-graphical utilities. These can be started from the NeuroTerm terminal window.
- `/neuro/bin/admin` -- scripts and binaries started by the CDE icons and other programs. Do not start them directly.
- `/neuro/bin/dicom` -- programs related to DICOM image transfers. Do not start them directly.
- `/neuro/bin/mri_admin` -- utilities for importing MR-images.
- `/neuro/dacq/bin` -- acquisition programs for both the workstation and the acquisition computer.

System data

- `/neuro/lisp` -- LISP code for the off-line signal processor program (Graph).
- `/neuro/lout` -- layouts of the plotting and source modelling programs.
- `/neuro/dacq/dau` -- fixed configuration files (channel assignments, calibrations, DAU programs) for the VME data acquisition systems.
- `/neuro/dacq/vxi` -- fixed configuration files (channel assignments, calibrations, DAU programs) for the VXI data acquisition systems.
- `/neuro/dacq/logs` -- log files for the acquisition system.
- `/neuro/dacq/tuning` -- SQUID tuning parameter files and various configuration files for the automatic tuner program.

3.1.2 Relevant configuration files

The following configuration files are stored on the acquisition workstation in the /neuro/dacq/setup directory:

- `janitor.config` -- MEG system janitor configuration
- `janitor_eeg.config` -- EEG system janitor configuration
- `megacq.defs.local` -- acquisition user interface configuration parameter values

- megacq.vars.local -- acquisition user interface configuration parameter types.

The following configuration files are stored on the acquisition workstation in the /neuro/dacq/setup/collector/conf directory:

- collector.cmd -- collector server channel assignment
- collector.defs -- collector server parameter values
- collector.cal -- ccalibration coefficients
- collector.pos -- MEG sensor position info
- collector.para -- collector server parameters

The following configuration file is stored on the acquisition workstation in the /neuro/ssp/ directory:

- online_supine.fif -- On-line SSP operator.
- online_upright.fif -- On-line SSP operator.

3.1.3 Commands of the janitor program

Warning: Do not change anything, unless you are quite certain about the changes needed.

The MEG and EEG servers are controlled through the janitor and janitor_eeg programs. Some of the commonly used commands are:

- ABOU
  Displays information about the server.
- BIAS
  Sets the bias current : BIAS [<ch>] <value> ...
- CONFIG
  Gets the current configuration, in other words, the contents of the .config file: CONFIG [device].
- CLIS
  Displays a list of all the clients.
- DUMP
  Dumps the state into /tmp/janitor.dump DUMP [initial | wanted | current].
- GATE
  Sets the gate voltage: GATE [<ch>] <value> ...
- HEAT
  Heats one channel: HEAT <ch-name>.
- HELIUM
  Measures the liquid helium level: HELIUM [nosync].
- HELP
  Displays a list of all commands; HELP <topic> is more specific.

- INIT
  Initializes all devices and the janitor service.
- LIST
  Lists some known objects: `LIST units [class]`.
- LOAD
  Loads a state from a file: `LOAD <file name>`.
- LOOP
  Closes or opens a flux-locked loop: `LOOP [<ch>] C | O`.
- MONI
  Shows, starts or stops monitoring: `MONI [OFF | ON]`.
- NAME
  Sets or asks your name: `NAME [<program name>]`.
- OFFSET
  Sets the offset voltage: `OFFSET [<ch>] <value>`.
- PASS homunculus122
  Enters the login password.
- QUIT
  Quits from the service and closes the connection.
- READ
  Reads the state of an item: `READ <unit> <item> [force]`.
- READREG
  Reads the contents of a register: `READREG <device> <slot> <register>`.
- SET
  Sets the value of an item: `SET <unit> <item> <value>`.
- STATE
  Asks the state of the parameters: `STATE unit [<unit>][<item>] | STATE device [<name>]`.
- STATUS
  Gets the device or slot status: `STATUS device [<devname>] | STATUS slot [<devname>] [slot]`.
- STRUCTURE
  Gets the hardware structure information: `STRUCTURE`.
- SYNC
  Synchronizes the registers in the electronics.
- TEST
  Tests the given device: `TEST <device> [<slot number> <# of trials>]`.

3.1.4 UNIX commands

The following are the most commonly used UNIX commands:

- man
  Display the manual page for a command: man <command>
- id
  Display the login and group names, and numbers of the current user.
- ls

Displays the contents of a directory. ls -l will display the owners, groups, file sizes and last modification dates of all files in a directory

- cp
  Copy a file from a directory to another: cp <path1> <path2>.
- mv
  To move a file from one directory to another: mv <path1> <path2>
- rm
  To delete a file. rm [-options] <filename>
- ps
  Display a list of processes running on the system
- kill
  Terminate a process: kill [-options] <process id>
- chmod
  Sets the permissions to a file For example: *chmod ug+w, o-rw janitor.powerup* enables the owner (u) and group (g) to write (w) to file janitor.powerup and disables both read (r) and write (w) access for users other than the owner of the file and the members of the associated group.

4

CHAPTER 4

Preventive Maintenance

4.1 Planning preventive maintenance

There are three kinds of preventive maintenance (PM):

1) Full PM, interval 1 - 2 year(s)

- Target is to fully go through the system related to all main modules in the system.
- Full PM is based on the evaluation of a local BU MEG technical specialist and it can be done either once a year or every second year. If the full PM is performed every second year, the interim PM is performed in between these PMs.

2) Interim PM, interval 1 year

- If the full PM is performed every second year, the interim PM is performed between the full PMs.

3) Lifter PM, interval 5 years

- Lifter PM is carried out every fifth year to secure the safe and problem-free functioning of the lifting mechanism.
- This plan is typically connected to either the full PM or interim PM, but can also be a separate preventive maintenance visit.

Table 4.1 Preventive maintenance plans

Plans / Module	Full PM	Interim PM	Lifter PM
Initial system check	X	X	X
Warm-up	X		
Vacuum pumping of siphons	X	X	

Chair checks	X	X	
Bed checks	X	X	
MSR checks	X	X	
Electronics	X	X	
Vacuum pumping of the dewar	X		
Insert wiring test	X		
Cool-down	X		
Initial testing after cool-down	X		
Safety exhaust check	X	X	
Lifting unit verification	X	X	X
Lifting unit maintenance			X
System verification	X	X	

4.2 PM tools and material

4.2.1 Special tools and material needed in PM

a Full PM

- Nitrogen gas (purity 99,95%) + pressure regulator (adjustable to 0 - 1…2 bar output pressure), needed cylinder volume is a minimum of 10 liters
- Liquid helium required by the cool-down for Day 3
- Liquid helium for the first refill after 2 - 3 days after the full PM cool-down
- Vacuum pump system
- Vacuum valve adapter
- KF25 vacuum flange to the 7-mm silicone hose adapter (this is included in the latest version of the Cryogenic Accessories Kit, check that this is available on site)
- Fixed siphon end flange to the 7-mm silicone hose adapter (this is included in the latest version of the Cryogenic Accessories Kit, check that this is available on site)
- 5 meters of clean silicone hose with the inside diameter of 7 mm
- Insert wiring tester + connection cables
- Multimeter (fluke or equal) with pin probes connectors and banana plug (4-mm) cables

- Silicone vacuum grease
- CDs to save final set-ups and measured data

Useful emergency spares recommended to be on site during the full PM:

- Preamplifier board
- Siphon vacuum valve o-rings
- Filters to siphons
- Rupture foil of safety exhaust

b Interim PM

- Vacuum pump siphons
- CDs to save final set-ups and measured data

Useful emergency spares recommended to be on site during the interim PM:

- Preamplifier board
- Siphon vacuum valve o-rings
- Filters to siphons

c Lifter PM

- Lifting ropes

d After PM

- Refill the Cryogenic Accessories Kit; add replacement for the material that has been used during PM or which is missing in the kit.

4.3 Overview of the PM schedule

The following time schedule is only tentative and is mainly meant to help in scheduling the activity before the visit, but it also gives advice on the work order in preventive maintenance.

1.Full PM

- Day 1
  - System check takes normally about 1 - 3 hour(s)

- Fixing of the possible problems notified by the customer takes 2 - 3 hours
- Warm-up:

  Step 1: Helium boil-off with heaters takes typically 2 - 3 hours, depending on the amount of helium inside the dewar

  Step 2: Continuation of heating with heaters to 80 K takes typically about 3 - 4 hours

  Step 3: Final warm-up to room temperature takes totally about 10 - 15 hours

- Day 2

  - Finalizing the warm-up to room temperature
  - Vacuum pumping of siphons takes 3 - 4 hours (this can be done parallel to some of the other steps)
  - Insert wire testing takes 3 - 4 hours
  - Vacuum pumping of the dewar

- Day 3

  - MSR check takes an hour
  - Electronics check takes an hour
  - Chair check takes an hour
  - Bed check takes half an hour
  - Preparations for the cool-down and cool-down takes 3 - 4 hours

- Day 4

  - Initial testing after the cool-down takes 2 - 3 hours
  - Lifting unit verification takes a half an hour
  - Final testing of the system takes 3 - 4 hours

2.Interim PM

- Day 1

  - System check takes normally about 1 - 3 hour(s)
  - Fixing of the possible problems notified by the customer takes 2 - 3 hours
  - Vacuum pumping of siphons takes 3 - 4 hours (this can be done parallel to some of the other steps)

- Day 2

  - MSR check takes an hour
  - Electronics check takes an hour
  - Chair check takes an hour

- Bed check takes half an hour
- Lifting unit verification takes half an hour
- Final testing of the system takes 3 - 4 hours

3.Lifter PM

- Day 1
  - System check takes 1 - 3 hour(s)
  - Fixing of the possible problems notified by the customer takes 2 - 3 hours
  - Lifting unit maintenance takes 2 - 3 hours
  - Lifting unit verification takes half an hour

4.4 Step by step instructions for PM

The individual preventive maintenance plans are built from so-called modules. This chapter provides the step-by-step instructions for the modules in different preventive maintenance plans.

4.4.1 System check module

1. Save the current set-up in the Squiddler program as a reference.

2. Check that the acquisition is generally working and the tuning is OK.

   Tune the channels if needed. If the channels have been re-tuned, save a new copy of the set-up.

3. Record 2-minutes of empty room data (either seated or supine).

   Collect new data for 120 seconds (sampling rate 1000 Hz, filter 300 Hz). Measure autotuner average white noise levels in the 10 - 75 -Hz range. Print out the graph. Average noise level should be less that 5.

   Note: If the system has problems, the location of the problem needs to be determined before the warm-up starts.

4. Check the helium boil-off rate and review the helium statistics collected.

   Note any systematic increase in the boil-off rate.

5. Check that no extra items have been glued or fixed to the surface of the dewar and remove them if necessary.

6. Clean the dewar surface with alcohol.

4.4.2 MSR checks

1. Check that the system is grounded by disconnecting the main ground strap measuring the resistance between the room wall and the main ground strap.

   The resistance should be more than 1kOhms.

2. If the resistance is less than 1 kOhms (typically close to 0 Ohms), the extra grounding needs to be identified and removed.

   Note: In some cases DC potential may disturb the insulation resistance measurement. Reversing the polarity may remove this disturbance.

3. Check that the door mechanism works properly.

4. Measure temperature and humidity inside the room and compare them with environmental requirements:

   Temperature range inside MSR: 20-28 degrees C

   Humidity: 40-70%

   If the limits are exceeded, make a note to the report and inform the customer.

5. Check the ramp of the room.

6. Check that no foreign objects have been brought into the room. Especially cables may cause disturbances.

7. Have the room cleaned up.

Note: If a vacuum cleaner or any other magnetic equipment must be used during the clean up, do it when the system has been warmed up.

4.4.3 Warm-up

1. Remove the top and the back covers of the probe unit.

2. Install the fixed siphon extension.

3. Connect a fixed siphon end flange adapter to the fixed siphon.

4. Connect a 7-mm silicone hose to the fixed adapter and lead the hose out of the shielded room (note, in this phase the fixed siphon is used as

an extra exhaust line).

5. Connect the multimeter to the PT100 resistor in the helium level/auxiliary box.

6. Remove the blind flange of the dewar vacuum port and attach the vacuum valve adapter on the vacuum port with the KF25 vacuum flange to the 7-mm silicone hose adapter with the clean silicone hose.

   Note 1: If the silicon hose has some dirt inside, this might contaminate the vacuum space and could cause artifacts in the MEG measurements.

   Note 2: Do not open the vacuum valve of the dewar at this point.

7. To switch on heaters with the janitor, perform the following commands

   a.Save janitor.config-file:
   cp -p /neuro/dacq/setup/janitor.config /neuro/dacq/setup/janitor.config.ok

   b.Copy warmup-file to janitor-file:
   cp -p /neuro/dacq/setup/janitor.config.warmup /neuro/dacq/setup/janitor.config

   c.Select RestartAcqPrograms with /b-option in Maintenance-window.

   d.Connect to janitor as root:
   telnet kaptah1 janitor
   pass homunculus122

   e.Heater-settings
   Master heater control on:
   set master_heater_control heat_switch 127

   Heaters on:
   set heater1 heat_on_off 1
   set heater2 heat_on_off 1
   set heater3 heat_on_off 1
   set heater4 heat_on_off 1
   set heater5 heat_on_off 1
   set heater6 heat_on_off 1
   set heater7 heat_on_off 1
   set heater8 heat_on_off 1
   set heater9 heat_on_off 1
   set heater10 heat_on_off 1
   set heater11 heat_on_off 1
   set heater12 heat_on_off 1
   set heater13 heat_on_off 1
   set heater14 heat_on_off 1
   set heater15 heat_on_off 1

set heater16 heat_on_off 1
set heater17 heat_on_off 1
set heater18 heat_on_off 1
set heater19 heat_on_off 1
set heater20 heat_on_off 1
set heater21 heat_on_off 1
set heater22 heat_on_off 1
set heater23 heat_on_off 1
set heater24 heat_on_off 1
set heater25 heat_on_off 1
set heater26 heat_on_off 1

Heaters off:
set heater1 heat_on_off 0
set heater2 heat_on_off 0
set heater3 heat_on_off 0
set heater4 heat_on_off 0
set heater5 heat_on_off 0
set heater6 heat_on_off 0
set heater7 heat_on_off 0
set heater8 heat_on_off 0
set heater9 heat_on_off 0
set heater10 heat_on_off 0
set heater11 heat_on_off 0
set heater12 heat_on_off 0
set heater13 heat_on_off 0
set heater14 heat_on_off 0
set heater15 heat_on_off 0
set heater16 heat_on_off 0
set heater17 heat_on_off 0
set heater18 heat_on_off 0
set heater19 heat_on_off 0
set heater20 heat_on_off 0
set heater21 heat_on_off 0
set heater22 heat_on_off 0
set heater23 heat_on_off 0
set heater24 heat_on_off 0
set heater25 heat_on_off 0
set heater26 heat_on_off 0

f.Restore initial settings:
cp -p /neuro/dacq/setup/janitor.config.ok /neuro/dacq/setup/janitor.config

g.Select RestartAcqPrograms with /b-option in Maintenance-window.

8. Switch on 12 lower section heaters and monitor the dewar pressure.

   The pressure should not exceed 0,1 bar in the dewar gauge. If pressure exceeds 0,1 bar, reduce the number of active heaters; if the pressure does not rise, increase the number of active heaters while monitoring the dewar pressure. Place paper towels under the fixed siphon tip to keep the electronics dry.

9. Monitor the resistance change in the multimeter.

   When the resistance value has reached 150 Ohms the temperature inside the dewar is c. 80 K. The He gas flow from the dewar should have stopped. The helmet surface will normally frost at this point. Protect the floor from moisture from the helmet surface and helium gas exhaust line (at fixed siphon area).

10. Switch on all the heaters in the dewar.

11. Connect the silicone hose to the nitrogen cylinder regulator.

12. Flush the hose with nitrogen gas, adjust the pressure for minimum flow.

13. Connect the hose into the KF25 / 7-mm adapter.

14. Add nitrogen gas into the vacuum, pinch the hose one meter form the valve adaptor with the left hand, open the dewar vacuum valve slightly until the nitrogen in the hose has flown (hose has gone flat) into the vacuum of the dewar.

15. Pinch the hose near the vacuum valve adapter with the right hand and release the hose in your left hand (the one meter is filled again).

16. Repeat this cycle (Steps 14 and 15) 10 to 15 times and close the vacuum valve immediately after the last cycle.

17. Connect a clean silicone hose to the fixed siphon adapter.

18. Start flushing the dewar with nitrogen.

19. Continue flushing of the dewar with nitrogen until the dewar volume has been flushed 3 to 4 times (flush volume is about 320 liters e.g. about 2-3 minutes constant flush), monitor the dewar pressure and reduce the nitrogen flow if the pressure increases.

20. Stop the nitrogen flushing.

21. Connect a normal fixed siphon plug to the fixed siphon.

22. Let the dewar warm up with the heaters until the multimeter reading is over 200 Ohms.

23. Switch off the heaters and return the Janitor configuration into the normal mode.

The dewar warm up takes about 10 - 15 hours.

Note: If you need to leave the site before the multimeter reading is 200 Ohms, it is absolutely necessary to switch off the heaters and preamplifier power supply.

4.4.4 Electronics -module

a General check points

1. Check all incoming cables for wear and verify the connections.

b Main electronics cabinet

1. Check that the fans are operating.
2. Check that the fuses are OK and replace them if necessary.
3. Check that the indicator lights are OK.
4. Clean the filters and replace them if necessary.
5. Vacuum clean the electronics cabinet.
6. Tighten the screws and fasten the cables.
7. Check the connectors and the door mechanisms.

c Stimulus electronics cabinet

1. Check that the indicator lights are OK.
2. Vacuum clean the stimulus electronics cabinet.
3. Tighten the screws and fasten the cables.
4. Check the connectors and the door mechanisms.
5. Check for inappropriate connections of equipment and correct if necessary.

d Computer system

1. Check and note the software versions and upgrade them if necessary.
2. Check and clean the keyboard.

3. Check and clean the mouse.
4. Remove dust and fingerprints from the monitor screens.
5. Check the fans of the workstation.
6. Vacuum clean the inner parts of the printer
7. Check the air filter and the fan of the printer.
8. Clean the printer according to its manual.
9. Check the cabling for inappropriately terminated LAN connectors or SCSI cables and correct if necessary.
10. Perform an overall visual inspection of the computer system hardware

e HPI system and 3D-digitizer

1. Check the HPI coils and cables.
2. Check the epoxy coating of the coils.
3. Replace worn coils.
4. Check the cables of the 3D-digitizer.
5. Check the function of the 3D-digitizer (using for example graph paper) and record the accuracy.
6. Clean the 3D-digitizer and chair.
7. Clean the goggles if necessary and check for wear.

f Helium level gauge

1. Check the functioning of the local gauge on the gantry.

g Intercom and video (if installed)

1. Check the intercom system; speakers and microphone.
2. Run an empty-room measurement using the intercom during the measurement and check that there is no increase in the noise.
3. Check the video monitor system.
4. Adjust the TV monitor for optimal contrast and brightness.
5. Clean the TV camera lens and monitor screen.

4.4.5 Vacuum pumping of siphons

a Fixed siphon

1. Remove the fixed siphon from the probe unit.

   Plug the opening for the fixed siphon on the top plate by using a rubber cork included in the cryo kit.

2. Warm up and dry the siphon.

3. Check the fixed siphon for wear.

4. Check the o-ring in the vacuum close valve by opening the valve counter clockwise and replace the o-ring if needed.

5. Screw in the siphon vacuum close valve.

6. Re-evacuate the fixed siphon vacuum.

   a) Connect a pumping line to the vacuum pump-out port and open the vacuum valve by turning the screw counter-clockwise. Be careful not to unscrew the screw completely.

   b) The residual vacuum pressure must be below 5*10-2 mbar (no-flow condition). Tighten the pump-out port screw.

7. Replace the cotton in the filter at the end of the fixed siphon.

   Make sure not to put too much filter material in.

8. Check the o-ring of the fixed siphon in the siphon feed-through on the top plate and grease slightly with silicon vacuum grease.

b Transfer siphon

1. Check the siphon for wear.

2. By interviewing the end users, find out whether there have been abnormally high transfer losses or cold siphon surface during the transfer.

3. Check the o-ring in the vacuum close valve by opening the valve counter clockwise and replace the o-ring if needed

4. Screw in the siphon vacuum close valve

5. Re-evacuate the siphon vacuum.

6. Connect a pumping line to the vacuum pump-out port and open the valve by turning the screw counter-clockwise.

   Be careful not to unscrew the screw completely. The residual vacuum pressure must be below 5 Pa (no-flow condition).

7. Tighten the pump-out port screw.

8. Check the o-ring on the nozzle of the siphon and grease slightly with silicon vacuum grease

4.4.6 Safety exhaust check

1. Check that the safety relief valve opens easily by prying it gently with your fingers.

2. Remove the safety exhaust duct from the top of the probe unit and check that the rupture foil unit is not damaged. The foil is covered with foam plastic damping pieces. Replace the foil if necessary. Put the foam plastic pieces back.

3. Put the duct back and check the duct and joints for wear. Replace if necessary.

4. Check the connection of the safety exhaust duct to the duct outside the room.

4.4.7 Lifter verification

1. Perform an overall check of the mechanical parts of the gantry.

2. Drive the gantry up and down a few times and make sure the indicator LEDs operate normally, showing the OK green LED lit in the supine and seated measurement positions and that the red fault LED does not come on at any time.

3. Check the ropes for wear and replace if necessary. The ropes must be replaced every 5 years.

4.4.8 Chair checks

1. Perform an overall check of the mechanical parts of the chair.

2. Check that the chair moves up and down without problems.

3. Turn the chair over on its left side (use cushioning material underneath to avoid scratching) and inspect the hydraulics for leaks.

4. Check the water reservoir and fill up if needed.

5. Return the chair to the normal position.

6. Check that the chair wheels roll free.

7. Check the locking of the chair wheels.

8. Check that the chair remains at a fixed height, supporting a person for at least 15 minutes.

4.4.9 Cleaning

1. Check that no extra items have been glued or fixed to the surface of the gantry or the chair. Remove if necessary.

2. Dust the gantry and chair surfaces with a damp cloth. Alcohol may be used if necessary to remove fingerprints and tape glue residues, for instance.

4.4.10 Cool down

1. Preparations

   a. Vacuum has reached the good level $5*10^{-2}$ mbar or higher in dewar. Normally vacuum pumping takes overnight (12 - 15 hours) to be ready. Vacuum pumping can be in progress until the cool down starts.

   b. Prepare a transfer siphon and other accessories for helium refill.

   c. The extension has been screwed on end of the fixed siphon.

   d. Multimeter is connected into the Liquid helium level gauge unit.

   e. All power is turned off from the system.

   f. All electrical stim cables are pulled into the simulus cabinet.

   g. Filter cabinet hatches and electronic cabinet doors are closed.

   h. Close the possible additional feed throughs.

2. Close the dewar vacuum valve and stop the vacuum pump.

3. Start filling in helium as in the normal refill. The pressure starts to oscillate inside the dewar pressure gauge.

   Remove the vacuum pump and accessories from the room.

4. The multimeter reading starts to decrease slowly from 230 Ohms.

5. When the multimeter reading reaches 150 Ohms:

   a. Remove the multimeter from the room.

   b. Close the MSR door.

   Note: The time period immediately after this is critical as the sensors are soon going to a superconducting state

6. Continue the helium transfer until the sound in the exhaust line goes silent, then pressure in dewar gauge drops close to 0 bar (the point when the system starts to collect He as liquid), continue transferring for about 10 minutes. After this time dewar should have about 10-15% liquid He.

7. Open the MSR door and perform the power up cycle to the electronics.

8. Turn on the He level meter and check the level of liquid helium in the dewar.

9. Run RestartAcquisitionPrograms from the maintenance folder.

10. Start acquisition and load the saved set up saved after tuning.

11. Check that the channels are working by using the Squiddler -program in tune mode with the X-Y display.
    All channels should show a tune "wave", but they might not be in correct tune with possible bias and offset errors. The errors will correct themselves later when the system stabilizes.

12. Check for the non-working channels. If the number of non working channels is 0-3, continue the helium transfer.
    With a large number (4 or more) of non-working channels, you need to do trouble shooting.

13. Continue the transfer until the transfer dewar is empty (the helium refill ball goes flat and the helium level meter does not increase) or the helium level meter shows 100 %.

    Note: The next refill is sooner than normally as the boil off of He is higher right after cool down.

14. Check the cryogenic kit, make a note of the parts and replace if necessary.

4.4.11 System performance verification

a Phantom test

1. Perform a standard phantom test for at least 10 dipoles.

2. Check the calibration of the system by comparing the mean dipole moment of the fitted dipoles with the calculated dipole moment and adjust if necessary.

b Noise test

1. Record at least 1 minute of raw data for noise analysis. See “MEG noise measurements” on page 83.

2. Perform the noise analysis. See “MEG noise data analysis” on page 83.

5

CHAPTER 5

Maintenance Checklists

5.1 System check

Table 5.1 Checklist for performing a system check

Action	Measure	Limit	OK/NOK
Save the current set-up in the Squiddler program as a reference		N/A	
Check that the acquisition is generally working and the tuning is OK.		N/A	
Record 2-minutes of empty room data (either seated or supine) Collect new data for 120 seconds (sampling rate 1000 Hz, filter 300 Hz). Measure white noise levels in the 10 - 75 -Hz range. Print out the graph.		<5 fT/SqrtHz	
Check the helium boil-off rate and review the helium statistics collected.		N/A	
Check that no extra items have been glued or fixed to the surface of the dewar and remove them if necessary		N/A	

5.2 Magnetically shielded room

Table 5.2 Checklist for the MSR

Action	Measure	Limit	OK/NOK
Grounding			

Table 5.2 Checklist for the MSR

Action	Measure	Limit	OK/NOK
Check that the system is grounded by disconnecting the main ground strap measuring the resistance between the room wall and the main ground strap		> 1 kohm	
Room installation			
Check that the door mechanism works properly		N/A	
Measure temperature and humidity inside the room, compare with environmental requirements		See Site Planning Guide	
Check the ramp of the room		N/A	
Cleaning			
Check that no foreign objects have been brought into the room that might cause disturbances.		N/A	
Have the room cleaned up		N/A	

5.3 The probe unit

Table 5.3 Checklist for the probe unit

Action	Measure	Limit	OK/NOK
Dewar performance			
Check the boiloff rate and review the Helium statistics collected.		See specifications	
Check for cold spots in the dewar		N/A	
Warmup			
Check when the vacuum has last been re-evacuated		12 months	
Perform complete warmup to room temperature		N/A	
Re-evacuate vacuum		< 5 Pa	
If total warmup is performed, check and grease slightly all the O-rings of the probe unit and inspect the safety exhaust rupture for leaks		N/A	
Cable check			
Check all incoming cables for wear and verify the connections.		N/A	
Cleaning			
Check that no extra items have been glued or fixed to the surface of the dewar.		N/A	
Clean the dewar surface with alcohol.		N/A	

5.4 Cryogenics

Table 5.4 Checklist for cryogenics

Action	Measure	Limit	OK/NOK
Fixed siphon			
Warm up and dry the siphon		N/A	
Check the fixed siphon for wear		N/A	

Table 5.4 Checklist for cryogenics

Action	Measure	Limit	OK/NOK
Re-evacuate the fixed siphon vaccum.		<5 Pa	
Replace the filter at the end of the fixed siphon.		N/A	
Check and grease slightly the O-ring on the fixed siphon feed through.		N/A	
Transfer siphon			
Check the siphon for wear.		N/A	
Interview end-users for abnormally high transfer losses or cold siphon surface during the transfer.		N/A	
Re-evacuate the siphon vacuum.		<5 Pa	
Grease slightly the O-ring on the nozzle of the siphon.		N/A	
Exhaust system			
Make a note of the dewar pressure while in normal operating mode		<2 kPa (0.02 bar)	
Warmup and dry exhaust tube if necessary.		N/A	
Re-evacuate the exhaust tube vacuum		<5 Pa	
Grease slightly the O-ring on the nozzle of the exhaust tube feed through		N/A	
Check the silicon hose and all hose connections for wear.		N/A	
Check the exhaust system outside the room.		N/A	
Safety exhaust system			
Verify that the safety relief valve opens easily by prying it gently with your fingers.		N/A	

Table 5.4 Checklist for cryogenics

Action	Measure	Limit	OK/NOK
Remove the safety exhaust duct from the top of the probe unit and verify that the rupture foil unit is not damaged.		N/A	
Put the duct back and check the duct and joints for wear.		N/A	
Check the saety exhaust duct outside the room.		N/A	

5.5 Gantry and chair

Table 5.5 Checklist for the gantry and chair

Action	Measure	Limit	OK/NOK
Gantry mechanism			
Perform an overall check of the mechanical parts of the gantry.		N/A	
Drive the gantry up and down a few times and make sure the indicator LEDs operate normally.		N/A	
Check the ropes for wear and replace if necessary.		<5 Years	
Chair mehanisms			
Perform overall check of the mechanical parts of the chair.		N/A	
Check that the chair moves up and down without problems.		N/A	
Turn the chair over on its left side and inspect the hydraulics for leaks.		N/A	
Top up the water reservoir if needed.		N/A	
Check the chair wheels for free running.		N/A	
Check that the chair remains at a fixed height supporting a person		15 minutes	
Cleaning			
Check that no extra items have been glued or fixed to the surface of the gantry or the chair.		N/A	
Dust the gantry and chair surfaces.		N/A	

5.6 Electronics cabinets

Table 5.6 Checklist for the electronics cabinets

Action	Measure	Limit	OK/NOK
Main electronics cabinet			

Table 5.6 Checklist for the electronics cabinets

Action	Measure	Limit	OK/NOK
Check that all fans are operating.		N/A	
Verify that all fuses are OK.		N/A	
Verify that indicator lights are OK		N/A	
Clean filters. Replace if necessary.		N/A	
Vacuum clean main electronics cabinet.		N/A	
Tighten screws and fasten cables.		N/A	
Check connectors and door mechanisms.		N/A	
Stimulus electronics cabinet			
Verify that indicator lights are OK.		N/A	
Vacuum clean stimulus electronics cabinet.		N/A	
Tighten screws and fasten cables.		N/A	
Check connectors and door mechanisms.		N/A	
Check for inappropriate connections of equipment and correct if necessary.		N/A	

5.7 Computer system

Table 5.7 Checklist for the computer system

Action	Measure	Limit	OK/NOK
Check and note software versions, upgrade if necessary.		N/A	
Clean the keyboard.		N/A	
Check and clean the mouse.		N/A	
Remove dust and fingerprints from the screen of the monitors.		N/A	
Check the fans of the workstations		N/A	
Vacuum clean the inner parts of the printer.		N/A	
Clean printer according to the printer manual.		N/A	
Check cabling for inappropriately terminated LAN connectors or SCSI cables and correct if necessary.		N/A	
Do an overall visual inspection of the computer system hardware installation.		N/A	

5.8 HPI system and 3D-digitzer

Table 5.8 Checklist for the HPI system and 3D-digitizer

Action	Measure	Limit	OK/NOK
Check the HPI coils and cables		N/A	
Check the cables of the 3D-digitizer.		N/A	
Check the function of the 3D-digitizer and record the accuracy.		N/A	
Clean the 3D-digitizer chair.		N/A	
Clean the goggles if necessary and check for wear.		N/A	

5.9 Helium level gauge

Table 5.9 Checklist for the Helium level gauge

Action	Measure	Limit	OK/NOK
Check the local gauge on the gantry		N/A	
Check the calibration of the He-gauge		<0% He	

5.10 Intercom and video (if installed)

Table 5.10 Checklist for the intercom and video

Action	Measure	Limit	OK/NOK
Check the intercom system, speakers and microphone.		N/A	
Run an empty-room measurement using the intercom during the measurement and check that there is no increase in the noise.		N/A	
Clean the video monitor system..		N/A	
Adjust TV monitor for optimal contrast and brightness.		N/A	
Clean TV camera lens and monitor screen.		N/A	

5.11 Cryogenic accessories box

Table 5.11 Checklist for the cryogenic accessories box

Action	Measure	Limit	OK/NOK
Check the cryo kit making a note of the parts and replace if necessary.		N/A	

5.12 Tuning

Table 5.12 Checklist for tuning

Action	Measure	Limit	OK/NOK
Check tuning of all channels.		N/A	

6

CHAPTER 6 **Troubleshooting**

6.1 Isolating the problem in MEG channels

In the tropubleshooting situation of MEG channel problems, it is improtant to try to isolate the problem when the system is cooled down. If the trouble shooting of cooled system shows, that the problem is inside the insert electronics, the system needs to be warmed up. Please consult with the MEG support before if you indentify the problem to be at the insert electronics, before doing maintenance actions to the insert electronics. In the following chapters, we explain the steps that one should take when troubleshooting a problem in MEG channels.

Isolating the problem in MEG channel while the device is still cold

In Elekta Neuromag -system, there are totally 26 identical MEG signal routes from SQUID sensors to Realtime computers. Figure 6.1 a) illustrates a simplifed view of two channels signal route in normal operating condition. This chapter defines how the signal route can be trouble shooted by isolating the different parts in the signal route. It is easiest to start working from the preamplifier printed circuit board (pcb) towards the real time computers following the signal flow. Below is an example of the trouble shooting a problem in MEG channels

Example: troubleshooting a problem in misbehaving MEG channels

Study the situation first by looking the channel data from the Data Acquisition work station raw display, use the below check list to trouble shoot the prolematic channels:

1. Check the channels from the raw display. Notice if there are several channels which have the problem or is it just one channel, write down the number(s) of the channel(s) which have problem(s).

2. Heat the channel(s) first, in order to release possible trapped magnetic flux and check the tuning curve of the channels which have problems.
3. If you have several problematic channels, try the effect of switching off the ssp vectors, as in some of the cases they can spread the problem of one channel to multiple channels. Check also from the operators, when the problem started and had there been any changes to the system connected to that when the problem started. If there has been changes to the system, check what those were and if noting else helps, you could at the later phase of the trouble shooting ask the operator to return the systemto the condition before the problem started

If there are only some channels that is problematic, try to isolate the problem. For this example we show how to isolate a problem in a MEG channel 0312 by swapping. Start from the preamplifier pcb:s

4. Start Swapping the SCSI cables of channel 3 and 4 from the connectros of the preamplifier pcb:s as shown in Figure 6.1b) and look then the Data Acquisition work station raw display

- If the problem which was earlier seen in the channel 0312 has now been tranferred to channel 0412, the problem is either the preamplifier pcb of channel 3 or the insert electronics in the dewar. By swapping the preamplifier pcb, you can check the condition of that. If the problem is in insert electronics, consult the support of MEG about the next actions, because the device has to likely be warmed up and the problem isolated with the insert wiring tester.
- If the problem does not transfer to the channel 0412, the problem is after the preamplifier pcb (looking the signal route towards the real time computers) in the SCSi cables or filter unit pcb or SQUID controller pcb. In order to study that continue with the next swap.

5. Swap the cables between the filter unit pcb:s and SQUID controller pcb:s of channels 3 and 4

- If the problem does not change to channel 0412, the problem is in SCSI cable or squid control pcb
- If the problem transferred to 0412, the fault is in filter unit pcb

Isolating the problem of MEG channel when the device has been warmed up

The insert wiring tester is plugged in in place of the preamp (3) and will isolate problems of the insert electronics, see more info about that in the chapter instructing the use of the insert wirring tester..

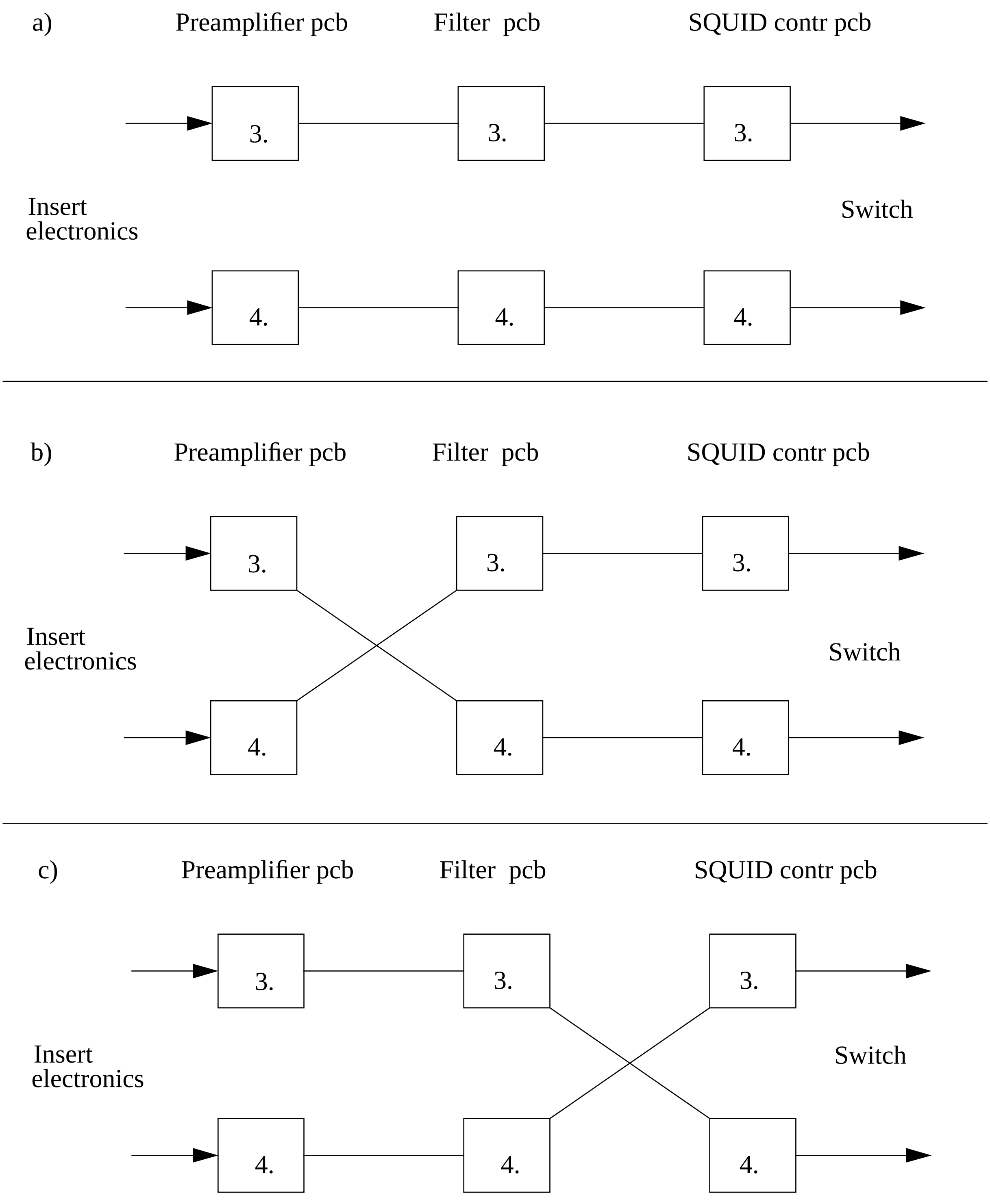


Figure 6.1 MEG signalling, simplified view

6.2 Common problems

6.2.1 Flat or noisy channels

1. If several channels show flat or noisy characteristics, first check the liquid helium level and transfer if necessary.

   The most common reason for flat or noisy behavior of a channel is improper tuning or magnetic flux trapped into the squid sensor. Look at the flux vs. current characteristics of the xy digital scope using the squiddler program (refer to the tuning instructions given in the Tuner Manual).

2. Check the following and adjust if necessary.

   Check that the modulation depth is not suppressed (there is no flux trap) by heating the sensor

   Check that the bias is optimal (curve not clipping or biased too high).

   Check that the offset is optimal (curve is crossing zero, not too close to peaks or valleys of the curve).

   Check that the gate is optimal (no instability is visible).

   Check that the curve is not skewed (no moisture problem).

   Check that the curve is not showing more periods than usual. (Compare with neighbour channels; this is to check whether the sensor unit input circuit is working properly. Replace if necessary.)

3. After this, fine-tune the noise adjustment mode.

   If the output cannot be corrected by tuning, try another working point by varying the bias to a higher value.

4. Adjust the offset and gate accordingly.

6.2.2 Artefacts

Try to remove the problem by simplifying the setup until the problem has been identified. Especially try to determine **which things have changed** since the system last operated without problems. The following are possible common causes of artefacts (the list is not exhaustive):

- Improper grounding of stimulators or other peripherals, causing currents to flow in the walls of the magnetic shield (stimulus artefacts, line interference, computer data transfer artefacts).

-> Check that grounding is single point only.

- Multiple grounding points due to imporperly added equipment (line interference).

  -> Check that grounding is single point only.

- RF interference from external sources caused by unfiltered cables to the inside of the MSR (increased noise).

  -> Check that only shielded leads are fed inside the shielded room.

- Active digital equipment in the stimulus cabinet, inducing interference to leads going inside the MSR.

  -> Shield the device, or preferably have it outside the stimulus cabinet and feed the signal through a feedthrough filter.

- Stimulus cables improperly connected (stimuli not coming, artefacts, line interference or RF interference).

  -> Check cabling.

- Magnetic objects near the sensor array lead trapping of flux in the sensors, causing flat or noisy channels.

  -> Detrap using sensor heaters.

6.2.3 Trapped flux in the sensors

Strong magnetic fields in the vicinity of the sensors may cause flux to be trapped inside the films. In particular if magnetized objects such as tools, steel buttons, magnetic electrodes or hairpins are brought inside the helmet against the surface, flux trapping may occur. Flux may become trapped into the SQUID if a current surge of big enough amplitude flows through the SQUID.

Trapped magnetic flux always reduces the critical currents of the SQUID. This is manifested as reduced modulation depth of the flux vs. current characteristics. The point of operation also changes as a result, the SQUID feedback loop may not lock any more after flux trapping or at least the noise level is greatly increased. In case of a sudden increase in noise and loss of the ability to lock the feedback loop, flux should be checked. If the maximum modulation depth drops below 25% of its original value (measured during installation) associated with a shift of the offset, flux trapping is likely. Carefully check the conditions under which flux trapping has occured so that further flux trapping can be avoided. Record and save the modulation depths of all the channels for future reference.

6.2.4 Excess moisture on the top plate

In humid conditions, condensation of water on top of the dewar may occur. Therefore the air in the magnetically shielded room must be conditioned to have a dew point which is at least 5 degrees C below room temperature. A recommended room temperature is 20 - 24 degrees C with 50% relative humidity. During helium transfer the top plate may get cooler than under normal conditions resulting in condensation of water.

Water in the top plate connector may cause leakage currents and polarization voltages between the pins of the connector. This may lead to a wide variety of disturbances observed in the normal measurement mode. To identify the problem caused by moisture, check whether there is water condensing on the top plate in the connector area and check the flux vs. current characteristics where the following phenomena may be observed (one of several):

- The flux vs. current characteristics gets skewed, see Figure 6.2 Flux vs. current characteristics gets skewed if there is leakage due to excess water.
- The amplitude of the flux vs. current characteristics may get smaller.
- The amount of flux caused by certain excitation may be lower than normally (less flux quanta).
- When observing the flux vs. current characteristics in the xy-mode, the trace is substantially phase shifted (see Figure 6.2 Flux vs. current characteristics gets skewed if there is leakage due to excess water).

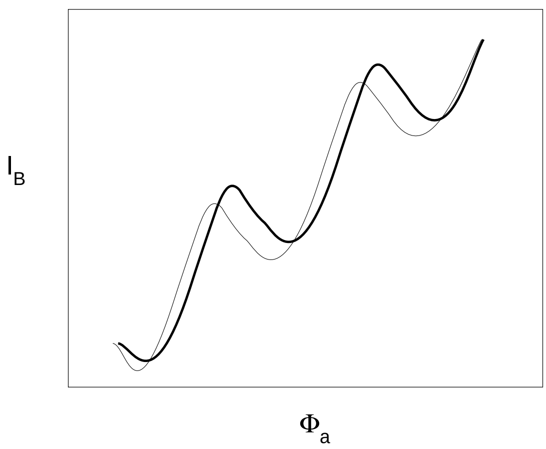


Figure 6.2 Flux vs. current characteristics gets notably skewed if there is leakage due to excess water

6.2.5 Helium boiloff

1. Check the log history to determine whether the He dewar has been filled appropriately.

2. Check that the surface of the dewar or siphons are not cold to the touch or have any ice formed on the surfaces.

3. Check that there is no physical damage to the dewar or helmet units.

6.2.6 Overheating (electronics, fans, filters)

The power source in the electronics cabinets will automatically shutdown if overheated (at approximately 40 degrees C). The recommended temperature for the electronics cabinet is 20 - 24 degrees C. If the electronics cabinet has overheated, make sure that all the fans are operational and that airflow to the filters is not obstructed in any way.

6.3 Software and networking toubleshooting

1. Check that all network cables are connected properly.

2. Check the network connections by *pinging* the IP addresses of the workstations as well as their hostnames which can be checked from */etc/hosts*.

6.3.1 Premature end of acquisition

The acquisition stops automatically when:

- Workstation cannot handle all the data quickly enough.
- Data transfer problem is detected in the front-end of the system.
- Workstation hard disk is about to fill up.

It is usually possible to continue just by pressing “GO” after saving the data.

If the acquisition crashes or hangs up, do the following:

1. Double-click on the **RestartAcqProcesses** icon found in the Maintenance folder and follow the instructions on the screen.

2. Restart **Acquisition**.

3. If the `janitor.powerup` file is not up-to-date, reload the SQUID tuning settings either using Squiddler or Autotuner.

6.3.2 Acquisition does not start

Check network connectionsby pinging `ping`: <*hostname*>.

Connecting and monitoring the servers.

Servers to connect:

- `collector_fork` (on the acquisition workstation *sinuhe*)
- `collector` (on the RT systems *kaptah1* and *kaptah2*)
- DSP (on all DSP boards: sqc01...sqc26, sam01...sam12, scc, fungen...)

1. Establish connection: `telnet` <*hostname*> `collector`.
2. Log in (not required for DSPs): `pass homunculus122`.
3. Turn on monitoring: `moni on`.
4. Turn on state tracking: `send on`.
5. Log off: `quit`.

7

CHAPTER 7 System Performance Verification

7.1 MEG testing

The MEG testing comprises the following phases:

1. MEG channel tuning and rough checking
2. Making the online SSP noise suppression vectors
3. Preliminary visual checking of the MEG channels with the on-line noise suppression
4. Noise data measurement
5. Analysis of the nois data
6. Phantom measurement
7. Analysis of phantom data.

7.1.1 MEG channel tuning & preliminary system checking

It is possible to give the channels a rough check immediately after the cool down. The insert temperature will stabilize in 12 - 24 hours. The final tuning can be done after that.

1. By manually tuninig, check that all channels are working.

   Refer to Chapter 7.6 in the *Sensor tuner user's guide* document (NM21283A).

2. Go to the **Measure mode** and check signals in the **Raw data** display.

3. If all channels are working, save the tuning parameters.

4. Tune the system with the Tuner program.

5. Check all channels in the **Raw data** display and save the parameters.

6. For Maxshield systems, check the operation of the feedforward system according to NM20594A-A and the feedback system according to NM23161Y.

7. Enter the results in the forms referred to in the instructions.

7.1.2 Making online SSP vectors

Signal space projection (SSP) vectors can be generated when all the channels are operating and are tuned correctly. The vectors are dependent on the position of the device, and that is why the vectors must to be made for both upright and supine position.

1. Record raw empty room data for both positions for at least one minute.

   Use 1000-Hz sampling, 330-Hz low pass and 0.1-Hz high pass filtration.

2. Save the data with a name like

   `empty_room_upright`

   or

   `empty_room_supine`

   and mark down the path where the file will be saved.

3. Monitor the channels raw data during the measurement to make sure that the signals do not saturate.

   If the signals saturate, the measurement must be repeated.

4. Start the Signal processor (Graph) program.

5. Load or create a Graph setup, which includes at least ssp and pca packages in addition to the basic setup.

6. Load the `magnetometer-noise.setup` file from the load settings tool bar (**File -> Load Settings**) if it is available.

   The file contains the needed widgets.

7. Otherwise load a basic setup and using the lisp command line at the top of the Graph window.

8. Load the following modules using the lisp commands:

   ```
   (require "pca")

   (require "ssp")

   (require "std-selections")
   ```

9. Now open the control panel from the displays tool bar.

10. Connect the widgets as follows:

    `file(diskfile) -> buffer(ringbuffer) -> meg(pick) ->`

    `ssp(suppressor) -> pick(pick) -> display(plotter)`

    Connect by moving the cursor on to the first widget, click the mouse right button, hold it down, drag the line to the second widget, and let go of the right button.

11. Double click the ssp widget and change the buffer size to 20000.

12. Then double click the ringbuffer widget and increase the buffer size to 1000000.

13. Double click the file widget and load the `empty_room_upright.fif` file from the directory where it had been saved.

Making the `all.fif` file

1. To choose all channels, double click the meg pick widget and type `MEG*` into the **Names** field.

   It may be necessary to cut and reconnect the display widget line to get the display updated.

2. By using the right mouse button, select a short time span of data (less than one second) on the display.

3. Then select **Make evoked file** from the **File** menu of the Graph window.
4. Name the file to be saved `all.fif`.

5. Double click the file widget and load the `empty_room_upright.fif` file from the directory where it had been saved.
6. Double click the meg pick widget and type `MEG*1` into the **Names** field to choose all the magnetometers.

   If there are known bad channels which will not be repaired now it is possible to list them in the **Ignore** field.

7. To update the display, it may be necessary to cut and reconnect the display widget line.

   Cut by clicking the right mouse button, hold it, and drag the scissors across the line.

8. On the Graph display window, open the resource task bar and enable the superpose function to get the signals stacked on top of each other.

9. On the scale window, click the **Autoscale** button and set the offset to zero.

10. By using the lower slider, check that the data contains low frequency interferences to be eliminated with the vectors.

    Make sure that channels do not saturate in the time span that will be chosen for vector generation.

11. At the top on the Lisp command line write

    ```
    (pca-on-widget "meg" X Y)
    ```

    where X is the beginning time for choosing from the file and Y is the end time for choosing from the file, and press Enter.

12. Select **SSP Dialog** from the **Commands** menu.

    It may be necessary to wait a moment on slower systems until the following selections can be made.

13. Select **Add PCA fields** from the **Actions** menu.

14. Select 8 vectors.

    You should get an entry like PCA[102,8] in the vector pool.

15. Click the entry and select **Explode** from the **Edit** menu.

    Now the vectors can be selected individually by clicking them.

16. Start with **PCA-v1** as it one corresponding to the largest singular value and then click the right arrow.

    The right arrow copies the vector to the SSP vector panel. The suppressor automatically turns on once there is at least one vector assigned to it. You should see a decreasing noise level on the display as more vectors are added.

17. Delete the vectors you do not need from the vector pool, then click **File -> Save** and give the file a name like

    ```
    /neuro/ssp/mag_ssp_upright.fif
    ```

    or

```
/neuro/ssp/mag_ssp_supine.fif
```

depending on wheather the loaded file was upright or supine.

Generally five vectors are enough for magnetometers and two to three for gradiometers. If more vectors are used, the raw data appears better. On the other hand, the bigger number of vectors also unnecessarily attenuate brain signals as well and complicate analysis.

18. Select a short time span (less than one second) of raw data on the display with the right mouse button. Then select **Make evoked file** in the **File** menu of the Graph window. Give the file a name like

    `/neuro/ssp/mag_names.fif`

19. Open a terminal window. Run

    `cd /neuro/ssp/` (cont.)
    `neuro/bin/util/add_proj_namelist -f` (cont.)
    `mag_names.fif mag_ssp_upright.fif`

    This step adds the channel names to the SSP vectors. This program is missing from older software distributions. Check also `/neuro/ssp` and `/tm` for the binary if you don't find it in `/neuro/bin/util`.

20. Go back to Step 5 and repeat the above steps for gradiometers.

    Delete the previous SSP vectors from the pool and SSP panels and set the meg pick widget "names" resource to

    MEG*2

    or

    MEG*3

    before doing the PCA for the gradiometers. Save the results to files like
    `/neuro/ssp/grad_ssp_upright.fif`
    or
    `/neuro/ssp/grad_ssp_supine.fif`

21. Combine the gradiometer and magnetometer SSP operators in the Source Modelling Program (Xfit).

22. Open an evoked response `all.fif` file.

    The file has data from all channels (both magnetometers and gradiometers).

23. Open the Projection window and use **File -> Load** to load your newly created

    `/neuro/ssp/grad_ssp_upright.fif`

    and

    `/neuro/ssp/mag_ssp_upright.fif`

    Check **Allow measurement ID mismatch** before loading the above files.

24. Select all the SSP vectors in the projection list.

    Click **File -> Save** and give the file a name like

    `/neuro/ssp/online_upright.fif`

    or

    `/neuro/ssp/online_supine.fif`

25. Check the file permissions and create a symbolic link as follows:

    ```
    cd /neuro/ssp

    chmod 644 online_upright.fif

    ln -s online_upright.fif online.fif
    ```

26. Go back to Step 5 and repeat the above with the raw data from the supine position.

    Remember to replace `upright` with `supine` in the file names.

27. Check the functionality of the created SSP operators.

    Start Acquisition. Open the **Scales** menu and click **SSP On/Off** to see that when the vectors are on the raw data display is less noisy.

    If the SSP operator is not functioning, it probably means that the `/neuro/ssp/online.fif` file (or the file it points to) does not contain valid SSP vectors or is unreadable.

    When both `online_upright.fif` and `online_supine:fif` are present, the Gantry Position Select utility (in Neuromag/Maintenance toolbox) can be used for switching between these two SSP operators. The newly selected operator is activated at the next acquisition start (**GO** button).

7.1.3 MEG noise measurements

Before noise measurement all channels must be operating well. The average noise level in the Tuner program (SSP activated) should be about 3 - 3,5fT/vHz or less. For MaxShield systems, refer to instruction NM23167Y-* as well.

1. From **Acquisition: control** select **Sampling rate 1kHz** and **Low pass filter 330Hz**.

2. Record at least 1-minute raw data for the noise analysis.

   Check that during recording channels stay operative.

   For Maxshield systems, use the active compensation feedback and the feedforward system (if installed).

7.1.4 MEG noise data analysis

1. Open a terminal window and issue the following command:

   ```
   /neuro/bin/util/maxfilter -nosss -f filename.fif
   ```

   where filename is the name given in previous step. This will produce a processed `filename_sss.fif` file .

2. Perform the noise analysis on the processed file according to NM20654Y-* (factory test) or NM20846A-* (installation test) with the Maxshield active feedback on.

3. Start the Graph program.

4. Load `magnetometer-noise.setup` from **File** > **Load settings**.

5. Open the just measured raw data.

6. Open the Graph control panel by clicking **Displays -> Control Panel**.

7. Select all magnetometers by writing MEG*1 to the names in the Pick widget.

8. Open **Resources** and set the display to the Superpose mode.

9. Click **Autoscale** in the Display Scale window and set the offset to zero.

10. Scroll the file and check that all channels are in the working area, in other words, check that signals do not go to the limit (flat).

11. Note the start and stop time for the good signal.

12. Write `(pca-on-widget "meg" X Y)` to the command line. X is the start time and Y is the stop time for the good signal. To execute press Enter.

13. Select **SSP Dialog** from the Commands menu.

14. Select **Add PCA fields, 8 vectors**.

15. On the left side window there is an 8*102 matrix.

16. Select the matrix and execute the explode command from the SSP Dialog window.

    The matrix explodes into 8 vectors.

17. Select 5 vectors from the top and activate them with the right arrow button.

    Vectors will be copied to the right side window in the SSP Dialog window. The program will apply the selected 5 vectors to the raw data. Check the operation of the vectors by selecting **On** and **Off** from the SSP Dialog window.

18. Write `(average X Y)` into the command line.

    X and Y are the same start and stop times of the good signal. After Y the signal must be good 10 seconds.

19. Check that the `histo.lsp` file is available.

20. Execute the `(require "histo")` command in the directory where `histo.lsp` is located.

21. The command loads a histogram calculating program for the Graph program.

22. Execute the `(histo 1 10)` command to calculate the average noise from 1 Hz to 10 Hz.

23. Save the results with the `(save-result "name of the file")` command.

24. Repeat the above for the following frequency range: 60 - 70Hz.

    (60Hz: 70-80Hz).

25. Repeat the whole noise analysis for the gradiometers.

Write MEG*2 and MEG*3 into the names in the Pick widget.

26. Check the results with the text editor.

    For the limits of the noise test , refer to NM23168 *.

27. Enter the results to the NM23168Y-* form .

7.2 Phantom test

7.2.1 Measurement

1. Connect the phantom excitation multiplexer into the multiplexer cable with a 25-pin connector which is under the side cover of the gantry.

2. Start the acquisition program.

   Select or create a project suitable for phantom measurement. Load the required measurement settings from a template file: Select **load measurement settings** from the **File** menu and select the file /neuro/dacq/setup/phantom.fif.

3. Digitize the HPI coil locations on the phantom.

   The cardinal points coincide with the HPI cols. Compare the digitized distances of the coils with the actual values to verify correct digitizer operation. Errors should be max. 1.0 mm.

4. Put the phantom into the sensor helmet of the probe unit and push against the helmet.

   The front coil should point somewhat upwards. Connect the 32-pair cable between the phantom excitation multiplexer and the phantom. Connect the separate HPI coil set connector of the phantom to the connector of the HPI cable connected to the HPI outlet undernearth the side cover of the gantry.

5. Start the measurement.

   Do the head position measurement in the usual way as described in the *Data acquisition User's Manual.*

6. Start the phantom dipole control utility program by double clicking it's icon in the **MEG: Maintenance** folder.

7. Activate dipole 1 by entering its number to the phantom dipole control dialogue and click **Do it**.

Use the default 1000-nAm dipole moment.

8. Check that the MEG signals (sine wave cycles) and triggers appear on the raw data display.

9. Activate **Average**.

   Wait until the limit of 100 epochs is reached.

10. Advance the dipole number in the phantom dipole control dialogue by one and click **Do it** again.

    When measuring many dipoles, it is advisable to reset the MEG channels between the dipoles (select **Tools -> Reset channels**).
    Go back to Step 8 and repeat the measurement for each phantom dipole.

11. When all phantom dipoles have been measured, stop the measurement and save the file.

    This file contains the responses of all measured dipoles, stored as different categories.

7.2.2 Data analysis

1.Open a terminal window. Depending on the system, proceed as follows:

- Systems with Maxshield , feedback active compensation on:

  Issue the command:

  /neuro/bin/util/maxfilter -v -frame head -f filename.fif

  where filename is the name given in previous step. This will produce a processed file filename_sss.fif.
- Systems without MaxShield, or feedback active compensation off.
  Issue the command:
  /neuro/bin/util/maxfilter -nosss -f filename.fif
  where filename is the name given in previous step. This will produce a processed file filename_nosss.fif.

2.Start the Source Modelling Program.

Open the processed file saved at previous step and pick up the first of the dipole categories. Set the sphere model origin to (0, 0, 0) in the head coordinate system, and set the baseline from -50 to 0 ms. Select "accurate coil definition" from the DipoleFit/Preferences menu. If the data file was processed with the -nosss option set filter to low-pass 35 Hz, width 5 Hz. Fit single dipoles to the second and third peaks (minimum and maximum) of the response. To catch the minimum and maximum automatically use the fit-to-mamimum feature: right-click to the signal waveform window and select "fit to max amp" and then shift-left-click over the second peak, relase mouse button and shift-left-click over the third peak. For further instructions on how to fit the dipoles, refer to *Source Modelling Software User's Guid*e. Repeat the fitting for all other dipoles.

3.Go to Dipole fitting window, select all fitted dipoles press the right button of the mouse and select **Print -> File**

In the saving options dialog, select column titles, Cartesian dipole coordinates, distance from origin, dipole moment and tab delimited output. If you intend to do further processing (see next step) on a spreadsheet using a PC with a decimal comma system, you may also want to select "decimal part separated by comma". Print out the file and attach it to the phantom test form NM23166Y-*.

4.Compare the localization results with the positions given in Table 1 and check that the peak-to-peak amplitudes roughly match with the dipole moment selected at step 7

Note that the Source modelling program displays the dipole moments (Q) as zero-to-peak values whereas phantom dipole select uses peak-to-peak values: calculate the peak-to-peak value as the sum of the two peaks (minimum and maximum) fitted for each dipole. Due to the finite precision of the physical dipole length, the measured dipole moments typically differ slightly from the nominal value. Calculate the error in position for each dipole the mean error for all dipoles, and the mean amplitude.

5.Fill out the results on the phantom test form.

The individual position differences should be less than 5 mm and the mean dipole moment within 5% from the nominal value. If you used a spreadsheet to calculate the results attach the printout.

7.3 EEG testing

7.3.1 Required items

The following items are required to perform the EEG testing:

- EEG signal terminators EL20814K
- EEG test signal adapter (Calibration adapter) with a 60-dB attenuator (EL20844K for 64 channels or EL20867K for 128 channels) with a copy of data sheet EL20844Y having the same serial number as the calbiration adapter.
- Utility programs: `/neuro/bin/util/fiff_downsample`
- Layout: `/neuro/lout/vv_eeg_all_test.lout`
- Graph-function: `/home/neuromag/lisp/print-rms.lsp`
- Graph-setups: `/home/neuromag/lisp/setup/eeg_spectra.setup /home/neuromag/lisp/setup/eeg-rms.lsp`
- Calibration instructions EL20868Y-*
- Test form EL20980Y-*.

Note: If the above-mentioned files cannot be found they can be obtained from Elekta Neuromag. Copy the files to appropriate locations.

7.3.2 Preamplifier control check

The following steps test the communications between the janitor_eeg software module and the EEG preamplifier hardware:

1. Check that the EEG system is powered.

2. On the acquisition workstation, open a connection to the janitor_eeg module by opening a terminal window and issuing the following commands:

   ```
   telnet kaptah2 janitor_eeg

   pass homunculus122

   init
   ```

3. To read the identification register of the EEG reference board in slot 0 of the EEG preamplifier case, issue the `readreg eeg 0 Id` command.

   The command should return a string like

   200 Register /eeg[0]/Id = 0xA1

where A1 is the revision of the control FPGA chip.

If not, check that the preamplifier power is on, the power/control cable is connected, optical fibres are connected properly at both ends, and that the parallel port cable between the EEG optodriver board and the corresponding real-time computer is connected.

If there is still no response, check that the EEG preamplifier is correctly assembled and that the board ID DIP switches are correctly set .

4. Repeat the previous command for slots 1 to 8 (or to 16 if there are 128 EEG channels) by changing the number in the `readreg eeg <x> Id` command

   where <x> = 1…8 or <x> = 1…16.

5. Exit the janitor_eeg by issuing the `quit` command.

7.3.3 Testing with the terminators

1. Connect the two terminators EL20814K to the EEG input connectors (D37 connectors on the side panel of the gantry).

   The two terminators are equivalent. Be sure not to use the Calibration adapter EL20844K or EL20867K at this step.

2. Start the acquisition program by double-clicking its icon in the Neuromag toolbox.

   Invoke Squiddler-EEG (EEG control program) from the **Tools** menu of the Acquisition control program.

3. Select **Initialize electronics** from the **Commands** menu of the EEG control so that the EEG electronics goes into its default mode.

   The per-channel parameters should now be as follows:

   Active: **Off**
   Gain: **5000** for unipolar channels (typically EEG1-EEG60 and EEG65-EEG128).
   For differential channels (typically EEG61- EEG64) the gain is 500 or 150, depending on the configuration (nothing is shown in the ALL mode)
   HPF: **0.1 Hz**
   Test Osc +input: **Off**
   Test Osc -input: **Off**

   The common parameters should now be as follows:

   Ref Source: **Ref Electrode**

Ref Test Osc: **Off**
Active ground: **Off** (depending on the configuration, this may also be "On" but switch it to "Off")
Test Osc: **Off**
Test Osc Amp: **490 Vpp @ Zel = 1 M Ohms**
Test Osc Freq: **20 Hz**

4. Select all EEG and MEG channels and set a 600-Hz sampling rate, 200-Hz low-pass and 0.1 Hz high-pass in the **Acquisition** menu of the Acquisition control program and start acquisition (hit GO).

Noise level check

1. Select the first EEG channel set in the raw data display.

2. Set the EEG scale to 20 Volts (this may vary slightly according to local line noise level).

3. Observe the noise level. If there are channels whose noise level exceeds that of other channels, follow the usual hardware debugging procedures (swapping parallel units temporarily, replacing boards) to fix those channels.

4. Repeat this for all other channel sets. Do not proceed until the hardware is acceptable.

Amplitude and phase check

1. Enable the test signals from the built-in signal generator; in the EEG control, click the **ALL** button (channel number field shows ALL), then click **Test Osc +input** to **On** and finally **Test Osc** to **On**.

2. Set the EEG scale of the raw data display to 300 µV. There should be a clean sinusoidal wave on all EEG channels. Every other channel should be 180 degrees out of phase (the test signal feed is inverted, not the input). The amplitude of the differential channels, typically EEG61-EEG64, can be different from that of the single-ended channels.

3. If signal is not obtained for some channels, check the signal cables (damaged pins on connectors) and try to swap cables and feedthrough filter units.

Channel assignment check

1. Click the **ALL** button again to go back to the individual channel control mode. Start from channel EEG001.

2. Click **Active** to **Off** while observing the corresponding trace on the raw data display; it should become flat.

3. Click the channel back **On**. The sinusoidal trace should appear again.

4. Advance to the next channel and do the same check. Check all the EEG channels this way.

5. If the on/off response is not seen, check whether the response can be seen in some other channel; in that case, signal cables have been swapped or preamplifier board addresses do not correspond to physical locations.

7.3.4 Common mode rejection and active ground test

Note: This test is performed only if the reference board has been exchanged.

1. Connect the test signal adapter (calibration adapter) EL20844K or EL20867K to the EEG inputs on the side panel of the gantry.

   Note that the D37 connectors are not equal: the connector with the switch must be connected to EEG connector EEG1-EEG32.

   Connect the input cable of the test signal adapter to the HPI connector, found on the right-hand side panel of the Vectorview gantry.

   Make sure that the switch on the test signal adapter is in the Test position.

2. Open a connection to the collector server by double-clicking the **Collector** icon in the Maintenance toolbox.

   Enter the `pass homunculus122` password.

3. Set the function generator amplitude by issuing the `vara phantomAmp 1.0` command to the collector (note the case!).

   This corresponds roughly to a 1 Vpp signal to the calibration adapter and, thus, 1 mVpp to the EEG amplifier.

4. Set up the on-line averager as follows:

Define event 1:

Event channel: **STI201**
Old state: **0/65535**
New state: **32/65535**

Make sure that STI201 is selected in the acquisition setup.activate category 1 by performing the following tasks:

Set 1 as the reference event.
Disable rejection by setting -1 to the MEG Amplitude field.
"Set the number of averages to 100.

Make sure that Ref Source is set to **Iso ground** and Active ground to **Off** in the Squiddler-EEG window.

5. Start the acquisition (hit GO).

6. Start the function generator by issuing the `phan 1` command to the collector.

   Set the EEG scale on the raw data display to 500 µV.

   Check that the function generator trigger pulses appear on STI016 on the raw data display, and that a clean burst of two sine wave cycles appears on all the channels in-phase. The burst should just fit the display.

   Click the Average check box on.

7. After 100 averages have been collected, stop acquisition and save the average file as `Isognd_no_act`.

   Select data plotter menu item File:load layout

   `vv_eeg_all_test.lout`

   and set the scale of the averages display parameters as follows:

   "Process:Scales: time -50…200 ms
   "Process:Scales: EEG amplitude -500…+500 µV
   "Process:Baselines: baseline -50…-20 ms, use baseline
   "Process:Filter: low-pass filter 40 Hz, width 20 Hz

   Check that the burst polarity is the same on all EEG channels and that its amplitude roughly matches the size of the viewport (the space reserved for display of each channel trace).

8. Change Ref Source to Ref el in the Squiddler-EEG window.

Leave Active ground to **Off**.

Set the number of averages to **400** in the averager parameters.

9. Start acquisition.

   Start the function generator by issuing the `phan 1` command to the collector.

   Set the EEG scale on the raw data display to 10 μV. The signal should be buried in noise in unipolar channels; in differential channels, the amplitude should be the same as in Step 7.

   Click the Average check box on.

10. After 400 averages have been collected, stop acquisition and save the average file as `Ref_el_no_act`.

    Set the scale of the averages display to 0.1 μV and the base line and filter settings as in Step 7. The amplitude of the burst should roughly match the size of the viewport in unipolar channels; in differential channels, the amplitude should be the same as in Step 7.

11. Change Active ground to **On** in the Squiddler-EEG window.

    Leave Ref Source to **Ref el**.

12. Repeat Step 9.

13. After 400 averages have been collected, stop acquisition and save the average file as `Ref_el_no_act`.

    Set the scale, baseline and filter of the averages display as in Step 10. The burst should be only barely visible or indistinguishable from noise in unipolar channels; in differential channels, the amplitude should be the same as in Step 7.

7.3.5 Calibration

Note: This test is performed only if any of the preamplifier boards or any of the EEG signal RF filter boards have been exchanged.

1. Verify the calibration by performing the calibration measurements as instructed in EL20868Y-*.

2. Check the results by calculating the difference of the sine wave burst maximum and minimum and comparing it with the real supplied preamplifier input voltage as described in the calibration instructions.

7.3.6 Noise measurement

Note: This test is performed only if any of the preamplifier boards or any of the EEG signal RF filter boards have been exchanged.

1. In the Squiddler-EEG set the parameters as follows:

   Gain of all channels: **5000**
   HPF: **0.03 Hz**
   Ref Source: **Ref el**
   Active ground: **On**

   Set the sampling frequency to 600 Hz, high-pass filter to 0.1 Hz and disable the averager by deactivating the category 1. Disconnect the cable of the calibration adapter connected to the HPI connector at the gantry side panel. (This is very important as this cable ties the isolated ground to the real ground and thus may cause excessive line frequency artefact under certain conditions.) Keep also the cable off the floor.

   Start acquisition and collect 1 minute of raw data. Save the file as `EEG noise`.

2. Use the following utility program to downsample the data by a factor of two:

   /neuro/bin/util/fiff_downsample 2
   EEG_noise.fif EEG_noise2.fif

3. Start the Graph program.

   Load the …/eeg_rms.setup settings where …/ is the directory path specified in Section 7.3.1. The setup creates the following widgets to the Control panel display:

eeg: EEG*
eeg-filter: pass-band (band-pass 0.1 100), pass-type :function
square: sqr
base: start 0 stop 60 (no-baseline off!)
sub: fsub
root: ssqrt

This setup calculates the rms-value of the noise in the 0.1…100 Hz band.

In the command line on the graph main window, enter the `(load "…/print-rms.lsp")` command, where …/ is the directory path specified in Section 7.3.1.

4. Open the EEG_noise2.fif file.

   Set the cursor using the rightmost mouse button to any point on the trace.

   Enter the `(print-rms "rms.txt")` command. This lists the rms amplitudes of each channel in units of [μ Vrms] to the rms.txt file (prepend appropriate directory path).

   Open a terminal window and enter the following commands:

```
cd <directory path given above>
more rms.txt
```

   The maximum value is 0,4 μ Vrms.

5. (This step is not performed if Step 4 has been skipped). If necessary, calculate the spectra and investigate them to find a reason for possible excessive noise. Calculate the spectra as follows:

   In Graph, issue the `(require "average")` command.

   Load the `…/eeg_spectra.setup` setup, where …/ is the directory path specified in Section 7.3.1. This setup creates the following widgets to the Control panel:

eeg: EEG*
win: start 0, end 4, translate
spectra: fft-size 2048, fft-step 1024, power, n-averages 1, window hanning
average: start 0 end 300, do-average
root: function ssqrt

Set the parameters to the average-mode: step, average-trigger (eeg 0) and average-window win from the Parameters:averager menu.

Open the EEG_noise.fif data file and enter the `(average 0 60)` command .

When the calculation of the averages is finished, inspect from the display averages whether the noise level in some channels is substantially different from the others, for example because of popcorn-noise. This is seen easiest if all channels are superimposed for a while by setting superpose on from Resources. Popcorn-noise manifests itself especially as increased low-frequency noise. Use, for example **scale 1e-7**, **offset 1**, **start 0 Hz**, and **length 100 Hz** in the display averages. Note that the noise level in differetial channels may be different than in unipolar channels. Identify channels with excessive noise, use also the pick-widget-eeg and display-widget-display as help. Suitable parameters for a display widget are for example **scale 1e-6**, **offset auto**, and **length 1 s**. If necessary (if no data is seen or a wrong number of channels is displayed) refresch the links to display widgets: drag, with the rightmost mouse button depressed, from the widget root to the widget averages and from the widget eeg to the widget display. Continue debugging as usual. If parts have been changed, appropriate parts of this test must be repeated.

7.4 Noise measurement testing

Before noise measurement all channels must be operating well. The average noise level in the Tuner program (SSP activated) should be about 3 - 3,5 fT/ ?Hz or less.

1. From **Acquisition: control** select the sampling rate **1kHz** and low pass filter **330Hz**.
2. Record at least 1-min raw data for the noise analysis. Check that during recording channels stay operative.
3. Start the Graph program.
4. Load magnetometer-noise.setup from the **File -> Load settings**.
5. Open the just measured raw data. Open the Graph control panel by clicking **Displays -> Control Panel**.
6. Select all magnetometers by writing MEG*1 to the names in the pick widget.
7. Open **Resources** and set display to the Superpose mode.
8. Click **Autoscale** in the Display Scale window and set Offset to zero.
9. Scroll the file and check that all channels are in the working area, in other words, signals do not go to the limit (flat).
10. Note the start and stop time for the good signal. Write `(pca-on-widget "meg" X Y)` to the command line. X is start time and Y stop time for the good signal. To execute, press Enter.
11. Select **SSP Dialog** from the **Commands** menu.
12. Select **Add PCA fields, 8 vectors**. On the left side windows appears 8*102 matrix.
13. Select matrix and execute the explode command from the SSP Dialog window. Matrix explodes into the 8 vectors.
14. Select 5 vectors from the top and activate them with the right arrow button. Vectors will be copied to the right side window in the SSP Dialog window.
15. Program will apply the selected 5 vectors to the raw data. You can check the operation of the vectors by selecting **On** and **Off** from **SSP Dialog**.

16. Write (average X Y) into the command line, where X and Y are the same start and stop times of the good signal. After Y the signal must be good for 10 seconds.

17. Check that the `histo.lsp` file is available.

18. Execute the `(require "histo")` command in the directory where histo.lsp is located.

19. Command load histogram calculating program for the Graph. Execute the `(histo 1 10)` command to calculate the average noise from 1Hz to 10Hz. Save results by `(save-result "name of the file")`.

20. Repeat the above for the frequency range 60 - 70Hz (60Hz: 70 - 80Hz).

21. Repeat the whole noise analysis for the gradiometers. Write MEG*2 and MEG*3 into the names in the pick widget.

7.5 Insert wiring test

7.5.1 Equipment needed

- Wring tester NM20413K (See Figure 7.1 Insert wiring tester.)
- Ribbon cable NM20181J, (64-pin with DIN 41612 8"Euro") connectors, 2pcs (See Figure 7.2 Ribbon test cable (2 pcs).)
- Test adapter EL201810 (See Figure 7.3 Test adapter.)
- Digital multimeter (Recommended models: Fluke 77, Fluke 73, or Fluke 79)
- Banana plug (4 mm) test leads, 2 pcs

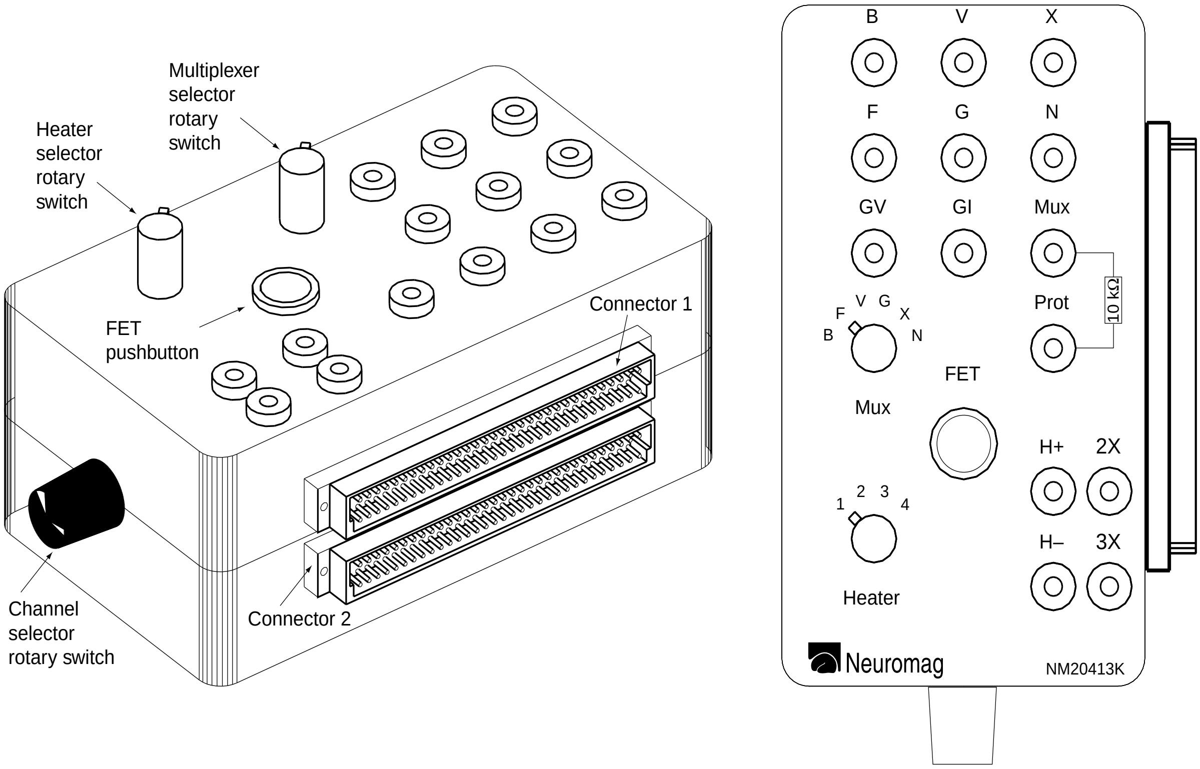


Figure 7.1 Insert wiring tester

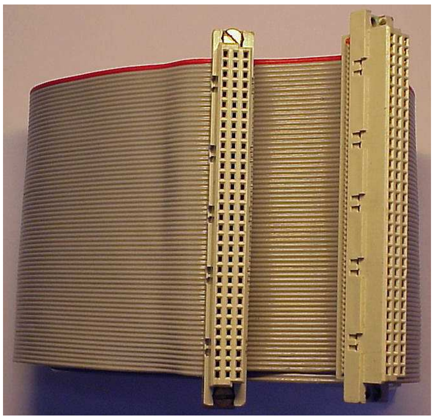


Figure 7.2 Ribbon test cable (2 pcs)

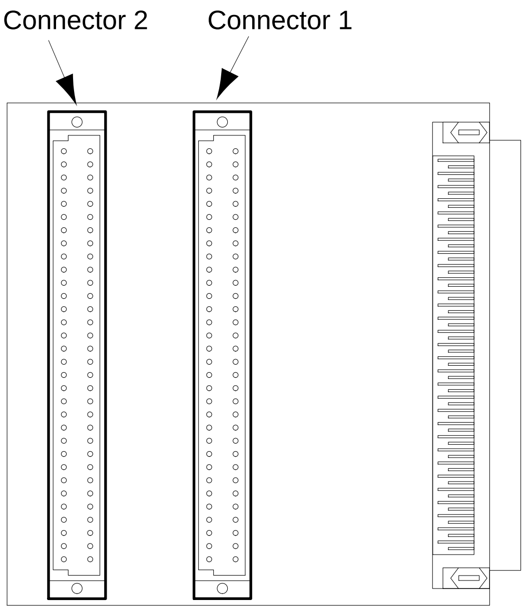


Figure 7.3 Test adapter

7.5.2 Channel numbering and conductor naming scheme

Each channel is identified by a 4-digit XXYZ code, where

- XX is the preamplifier number 1 - 26
- Y is the sensor element number 1 - 4 connected to preamplifier XX
- Z is 1 for the magnetometer and 2 or 3 for the gradiometer channels.

In the wiring tester the channels are marked Y.Z and the preamplifier XX is selected by inserting the test adapter into the corresponding preamplifier slot. See Figure 7.4 Insert top plate with preamplifier numbers indicated.

Note: Preamplifier slot 8 contains only sensor elements 1 and 2. Other preamplifier slots are identical with all the sensor elements 1 - 4 connected.

Note: Preamplifiers are numbered from 1 - 26. This is not to be confused with the board address 0 - 25 used by the janitor program. The corresponding board address is obtained by subtracting one from the preamplifier number.

Each sensor element has 22 conductors from room temperature to liquid helium space. These comprise 6 conductors per channel plus four conductors common to the sensor element.

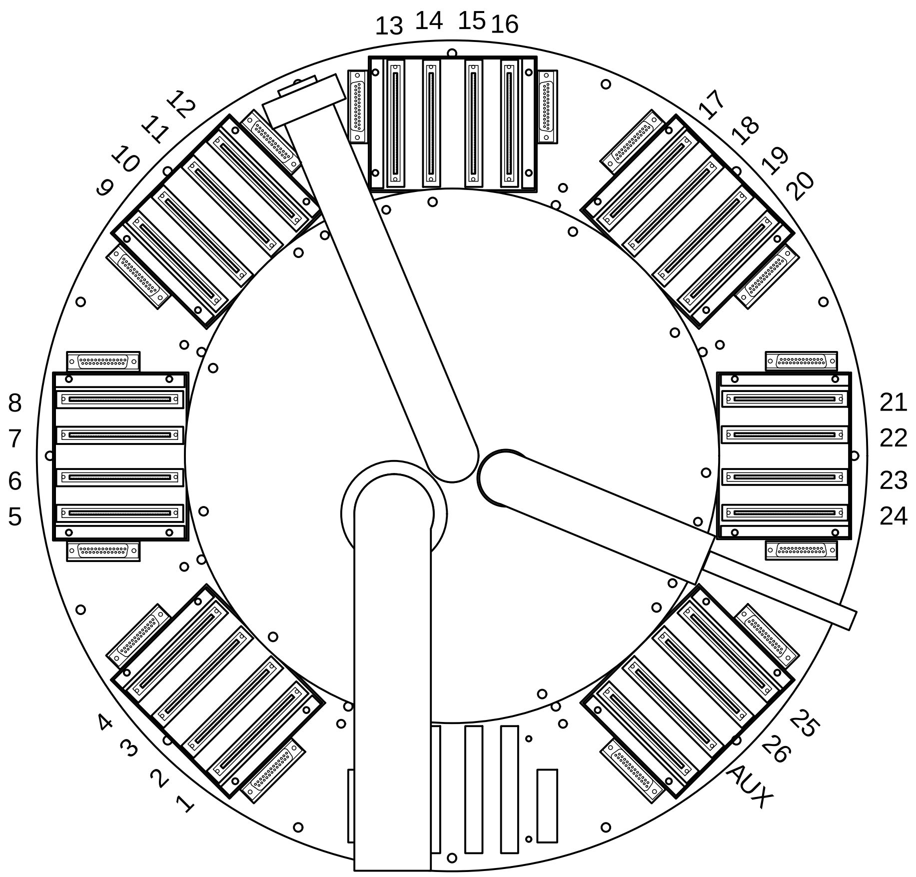


Figure 7.4 Insert top plate with preamplifier numbers indicated

The separate conductors for each channel 1 - 3 are the following:

- B Bias
- V Voltage measurement +
- G Voltage measurment - (ground, no current)
- F Flux feedback
- N Noise cancellation
- X Extra (see below).

The conductors common for the sensor element are the following:

- GV Common (active) ground voltage measurement
- GI Common (active) ground current return
- H+ Heater +
- H- Heater -.

The extra conductor (X) in channels 2 and 3 is used for doubling the heater wiring. In magnetometer channel 1 the X wire is connected to ground.

7.5.3 Equivalent circuit for the insert

To find out the equivalent circuit for the insert SQUID channels, see Figure 7.5 Equivalent circuit for the insert. Note that the extra conductor (X) is used for doubling the heater wiring in channels 2 and 3, and in magnetometer channel 1 the X wire is connected to ground.

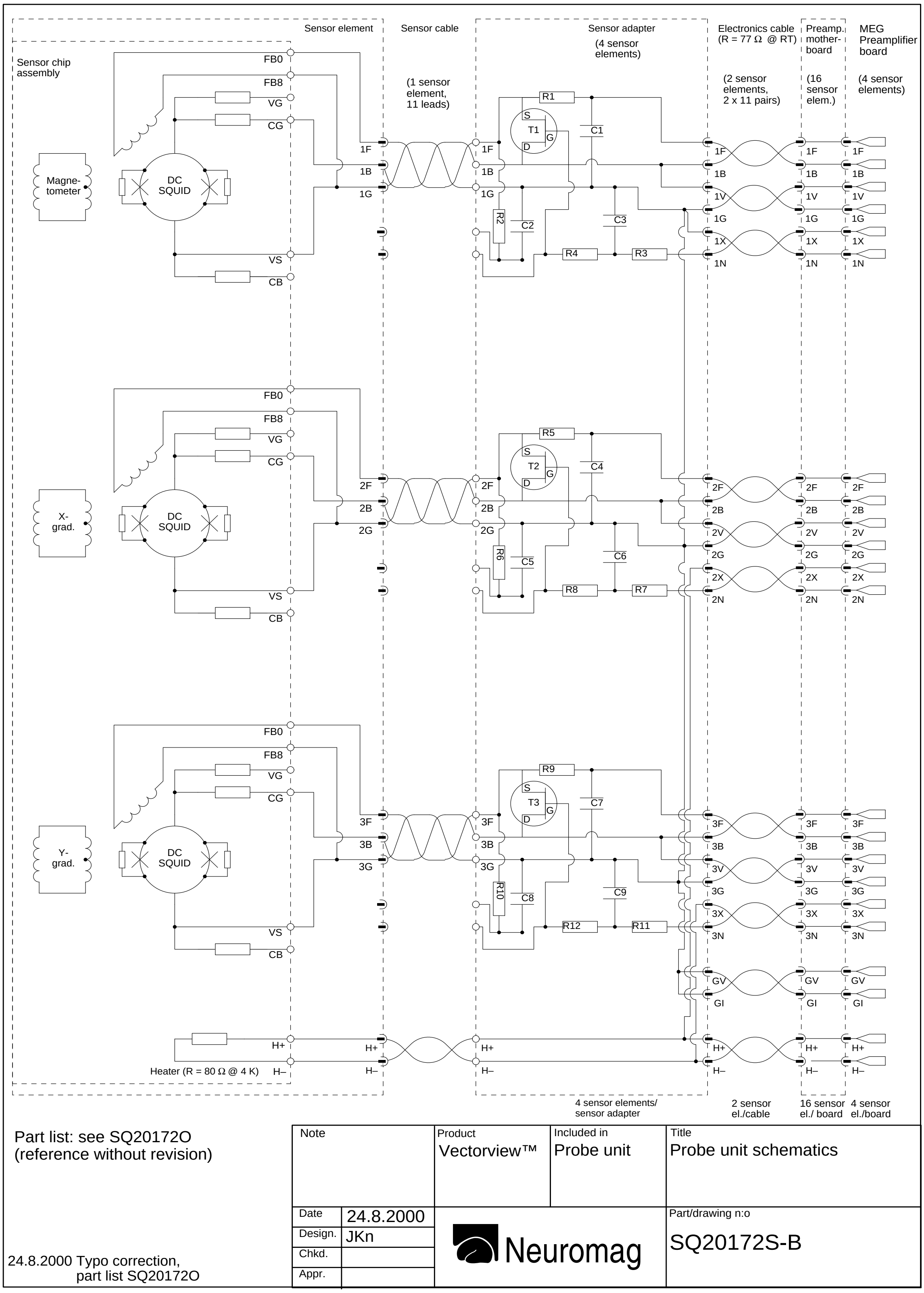


Figure 7.5 Equivalent circuit for the insert

7.5.4 Test procedure

The following procedure describes a complete test of the insert wiring. Even when testing a single channel only it is advisable to take reference readings from neighbor channels.

Note: Preamplifier slot number 8 is different from all others, see below.

Note: The insert contains components which may be permanently damaged by static electricity. Proper precautions such as wearing grounding wrist straps must be taken.

1. Insert the test adapter to the preamplifier slot to be investigated. Connect the ribbon cables between the respective connectors of the test adapter and the tester. Connect the multimeter common terminal to GI.

2. Connect the multimeter ohms terminal to GV. Go through channel selector positions 1.1 - 4.3. The correct reading is (130 ±30) Ohms.

3. Connect the multimeter ohms terminal to the protected Prot terminal.

4. Switch the multiplexer Mux rotary switch to position B and the channel selector to 1.1. The correct reading is (10.2 ±0.2) kOhms.

5. Switch the multiplexer Mux rotary switch to position F and the channel selector positions 1.1 - 4.3. The correct reading is (20.2± 0.2) kOhms (unchanged) if the system is in the superconducting state and about 40 - 50 kOhms if the system is in the normal state. The pressing of the button decouples the current path from feedback to B and V via the FET, forcing all current to flow through the feedback coil. The actual reading in the normal (non-superconducting) state may vary significantly depending on the individual parameters of both the FET and the coil. A clear change (≥1 kOhms) in the resistance should, however, be observed. An open circuit reading indicates a problem in the sensor adapter-wiring unit or the sensor itself. Release the button and observe that the reading goes back to its original value. Repeat the test for channel selector positions 1.1 - 4.3.

Note: Sometimes the autoranging circuitry of the digital multimeter gets confused when the FET button is depressed, resulting in erroneous display (flashing or oscillating between the two values). If this happens, try manual ranging of the multimeter.

6. Switch the multiplexer Mux rotary switch to position V. Go through channel selector positions 1.1 - 4.3. The correct reading is (10.2 ±0.2) kOhms.

7. Switch the Mux multiplexer rotary switch to position G. Go through channel selector positions 1.1 - 4.3. The correct reading is (10.1 ±0.1) kOhms.

8. Switch the multiplexer Mux rotary switch to position X. Go through channel selector positions 1.1 - 4.3. The correct reading is (10.2 ±0.2) kOhms in magnetometer channels (1) and open circuit (>1 MOhms) in gradiometers (2 and 3).

9. Switch the multiplexer Mux rotary switch to position N. Go through channel selector positions 1.1 - 4.3. The correct reading is over 10 MOhms in the superconducting state and about 3 MOhms when the system is at room temperature.

Note: The actual resisttance values vary considerably from one FET to another.

Heater test

1. Connect the multimeter ohms terminal to H+. Go through heater selector positions 1 - 4. The correct reading is (180 ±50) Ohms if the system is in the superconducting state and (400...1100) Ohms if the system is at room temperature.

2. Connect the multimeter ohms terminal to 2X and the common terminal to 3X. Go through heater selector positions 1 - 4. The correct reading is (180 ±50) Ohms if the system is in the superconducting state and (400...1100) Ohms if the system is at room temperature.

3. Connect the multimeter ohms terminal to H+ and the common terminal to 2X. Go through heater selector positions 1 - 4. The correct reading is (130 ±30) Ohms.

4. Connect the multimeter ohms terminal to H- and the common terminal to 3X. Go through heater selector positions 1 - 4. The correct reading is (130 ±30) Ohms.

7.5.5 Testing for cross-talk between channels

The wiring tester is designed for measuring only one channel at a time, and normally this is sufficient. If inter-channel cross-talk is suspected, readings must be taken directly from the test adapter Euro-64 connectors. See Figure 7.6 Pinout of the test adapter. Note that the channels in the same sensor element XXY1-XXY3 share a common ground; thus there are a lot of apparent interconnections between the channels. See Figure 7.5 Equivalent circuit for the insert. However there should be no interconnections between channels in *different* sensor elements.

Note: An external 10-kOhms resistor in series with the multimeter test must be used to prevent damage due to static electricity.

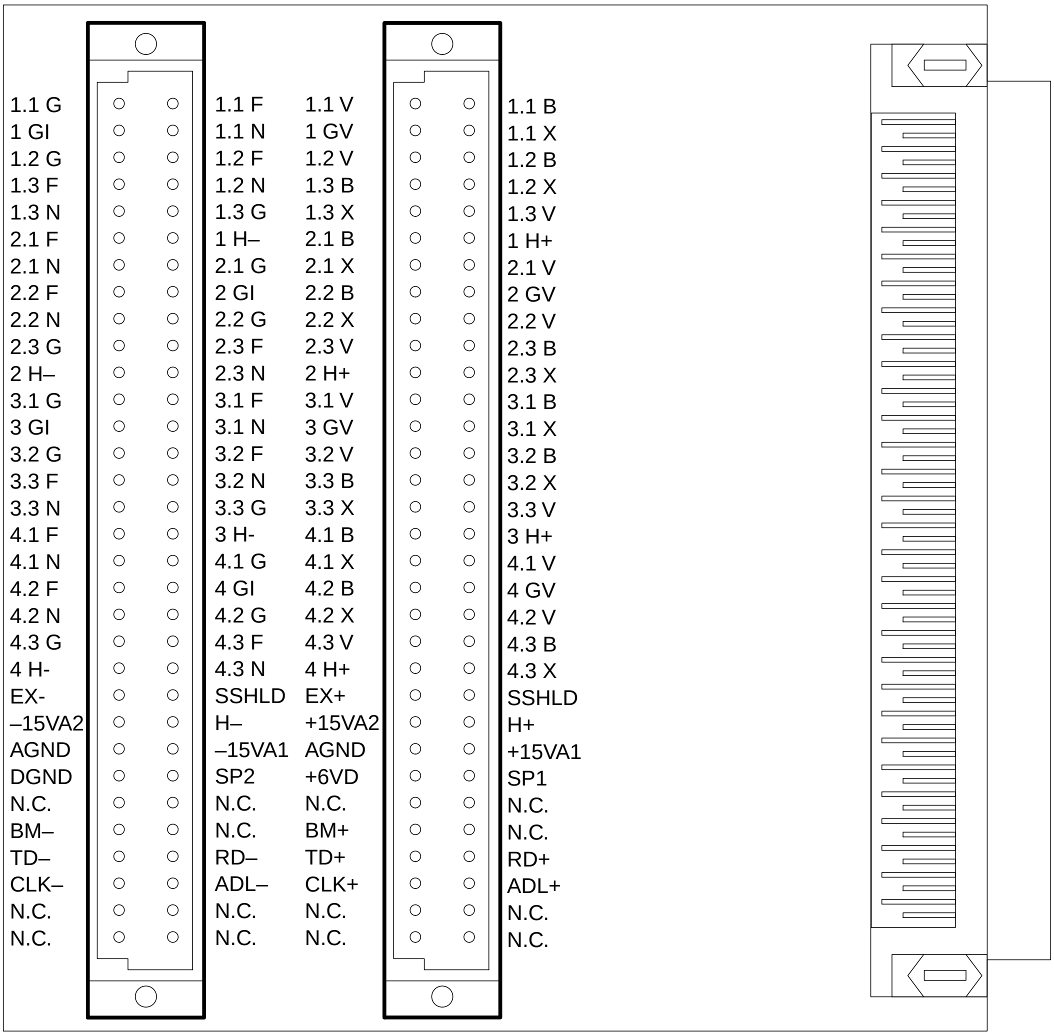


Figure 7.6 Pinout of the test adapter

7.5.6 Helium level probe and thermometers

For the equivalent circuit for the helium level probe and the two thermometers, see Figure 7.7 Equivalent circuit for the liquid helium level probe (R_p) and the thermometers ($R_{t1,t2}$).

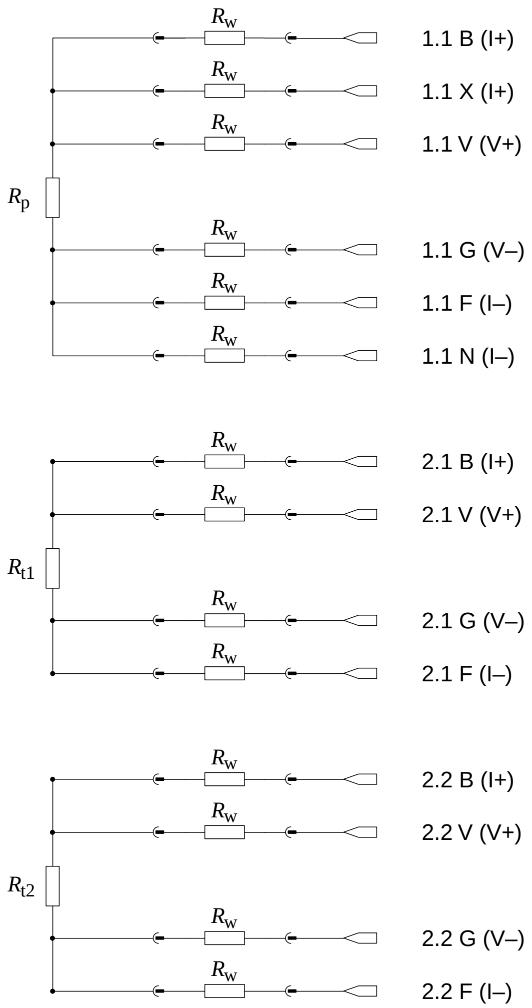


Figure 7.7 Equivalent circuit for the liquid helium level probe (R_p) and the thermometers ($R_{t1,t2}$). Nominal values for the resistors are: R_w = 65 Ohms, R_p = 300 Ohms at room temperature R_p = 0-250 Ohms at 4 K $R_{t1,t2}$ = 100 Ohms at room temperature and about $R_{t1,t2}$ 0.5 Ohms at 4K.

1. Put the test adapter into the Aux slot (number 27).

2. Set the channel selector rotary switch to position 1.1.

3. Connect the multimeter ohms terminal to B and the common terminal to F. The correct reading is (130 $\pm$30) Ohms if the system is in the superconducting state and (430 $\pm$30) Ohms if the system is at room temperature.

4. Connect the multimeter ohms terminal to V and the common terminal to G. The correct reading is (130 $\pm$30) Ohms if the system is in the superconducting state and (430 $\pm$30) Ohms if the system is at room temperature.

5. Connect the multimeter ohms terminal to X and the common terminal to N. The correct reading is (130 ±30) Ohms if the system is in the superconducting state and (430 ±30) Ohms if the system is at room temperature.

6. Connect the multimeter ohms terminal to B and the common terminal to V. The correct reading is (130 ±30) Ohms.

7. Connect the multimeter ohms terminal to X and the common terminal to V. The correct reading is (130 ±30) Ohms.

8. Connect the multimeter ohms terminal to F and the common terminal to G. The correct reading is (130 ±30) Ohms.

9. Connect the multimeter ohms terminal to N and the common terminal to G. The correct reading is (130 ±30) Ohms.

10. Set the channel selector rotary switch to position 2.1.

11. Connect the multimeter ohms terminal to B and the common terminal to F. The correct reading is (130 ±30) Ohms if the system is in the superconducting state and (230 ±30) Ohms if the system is at room temperature.

12. Connect the multimeter ohms terminal to V and the common terminal to G. The correct reading is (130 ±30) Ohms if the system is in the superconducting state and (230± 30) Ohms if the system is at room temperature.

13. Connect the multimeter ohms terminal to B and the common terminal to V. The correct reading is (130 ±30) Ohms.

14. Connect the multimeter ohms terminal to F and the common terminal to G. The correct reading is (130 ±30) Ohms.

15. Set the channel selector rotary switch to position 2.2.

16. Repeat Steps 8 - 11.

APPENDIX A Technical diagrams

A.1 Electronics diagrams

A.1.1 System diagrams

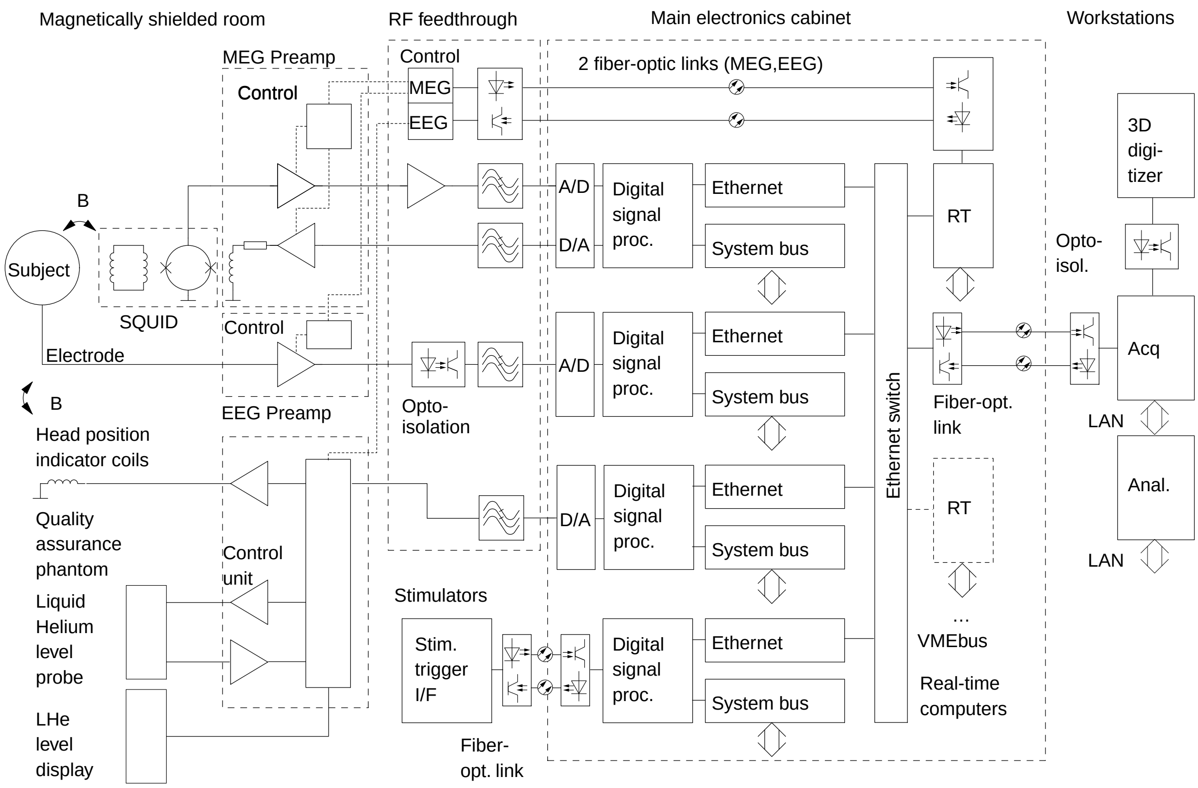


Figure A.1 Schematic diagram of the electronics

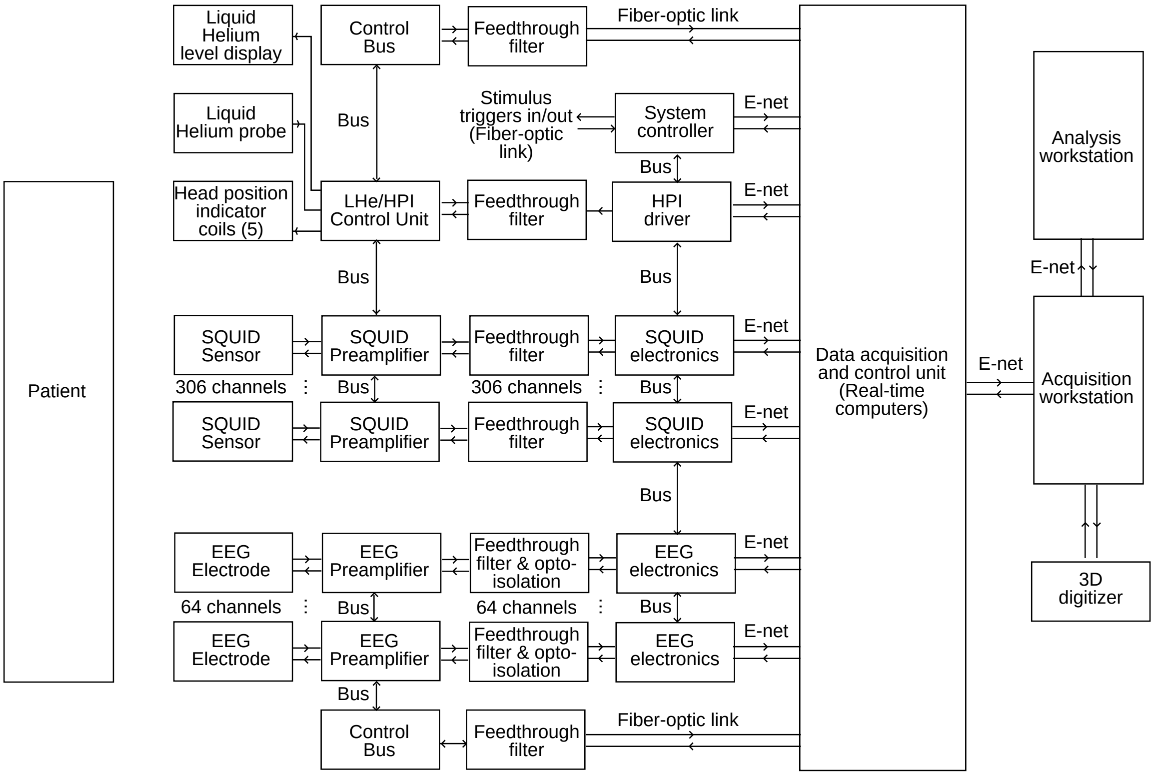


Figure A.2 Block diagram of the electronics

A.1.2 EEG electronics

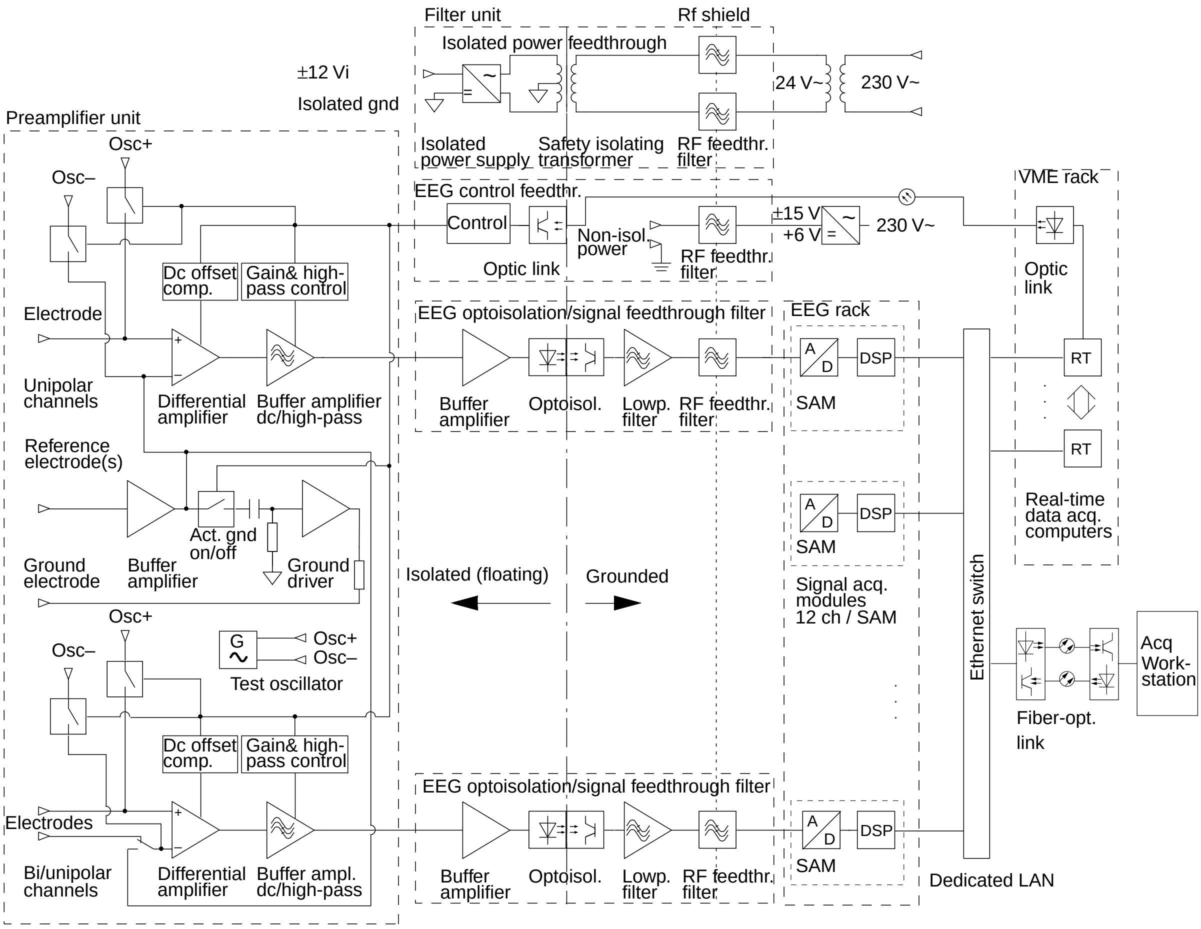


Figure A.3 Schematig diagram of the EEG electronics

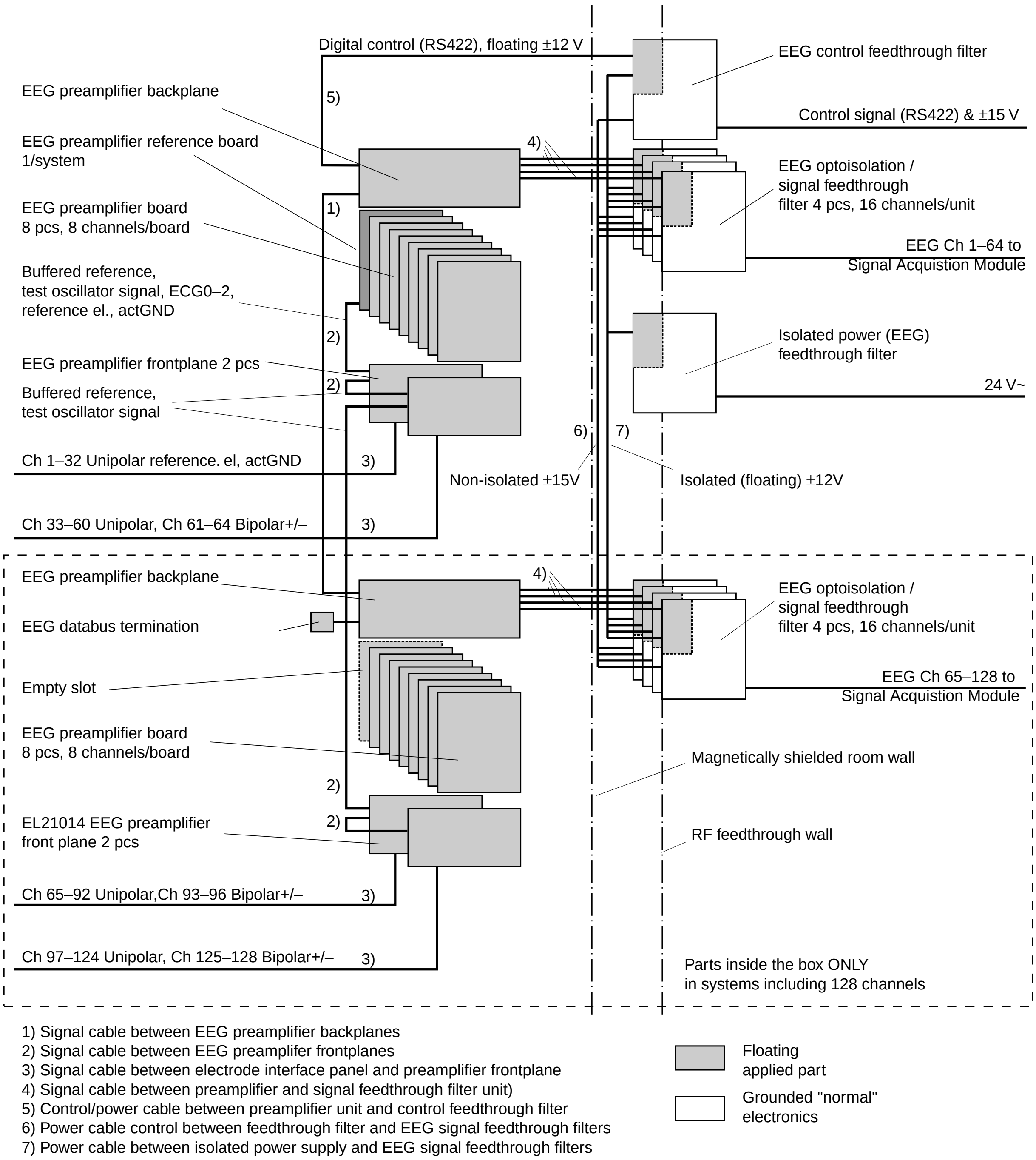


Figure A.4 Block diagram of the EEG electronics

A.1.3 Auxiliary electronics

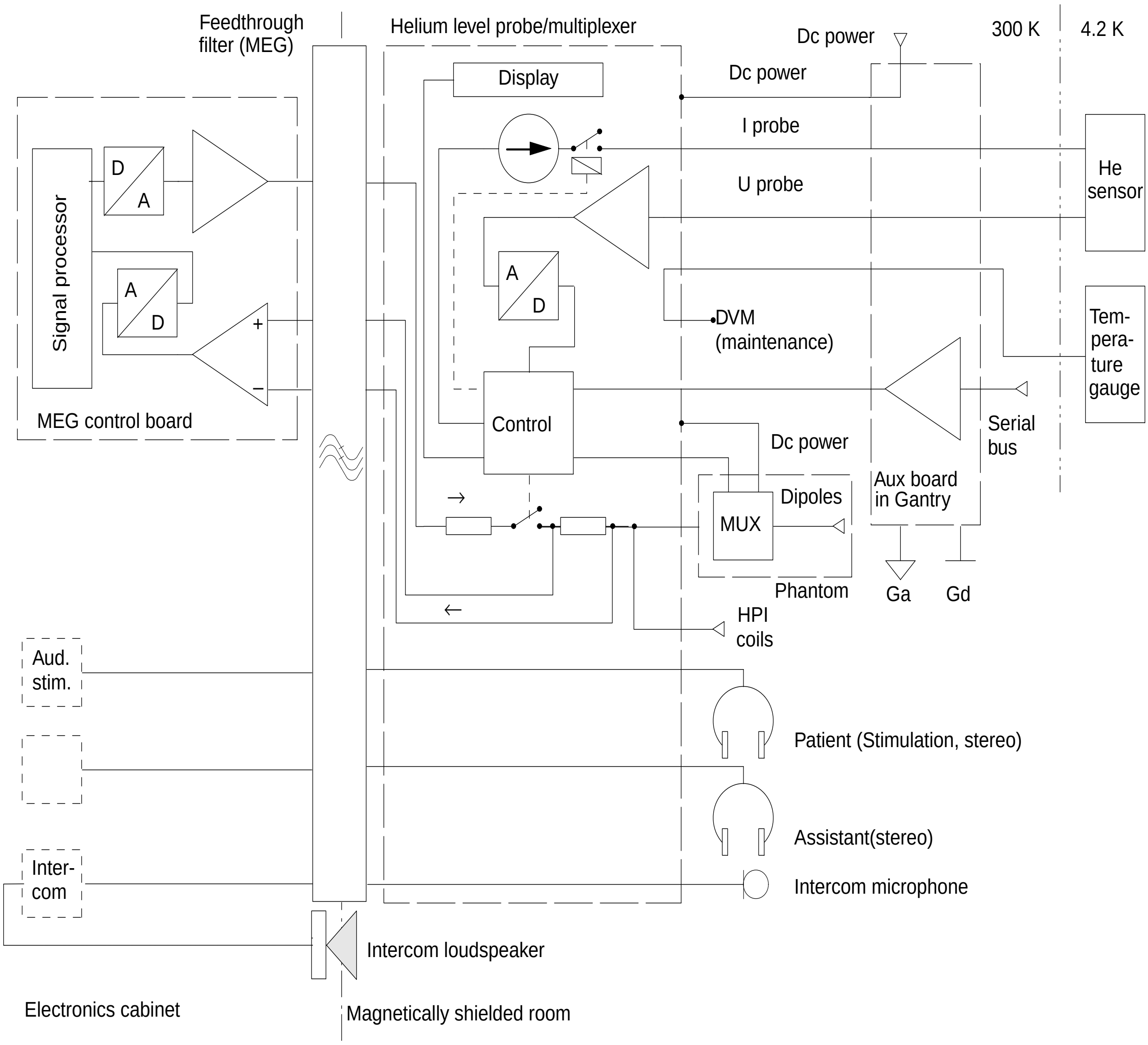


Figure A.5 Schematic diagram of auxiliary electronics

A.1.4 Lifting mechanism

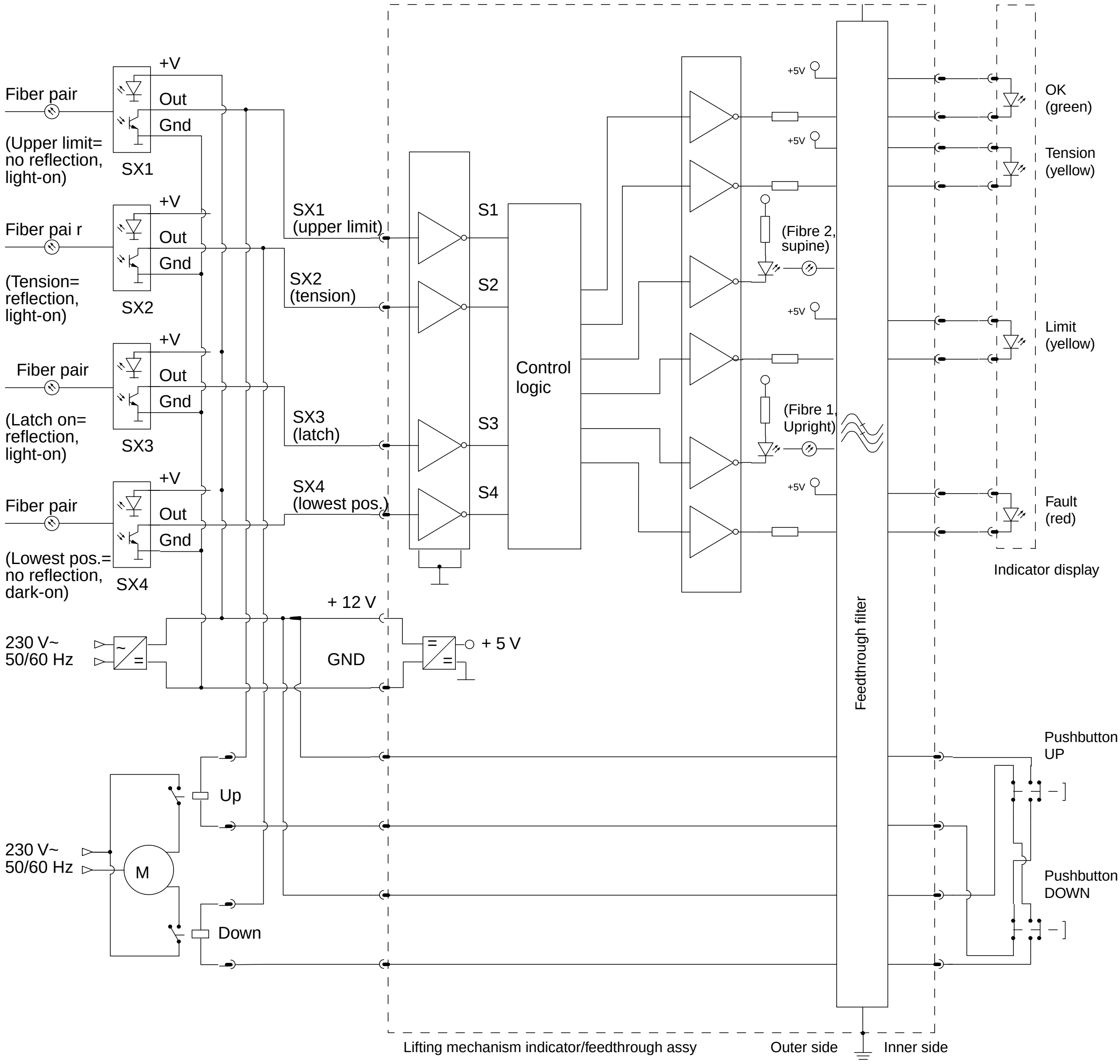


Figure A.6 Schematic diagram of lifting mechanism electronics

A.2 Electronics cabinet

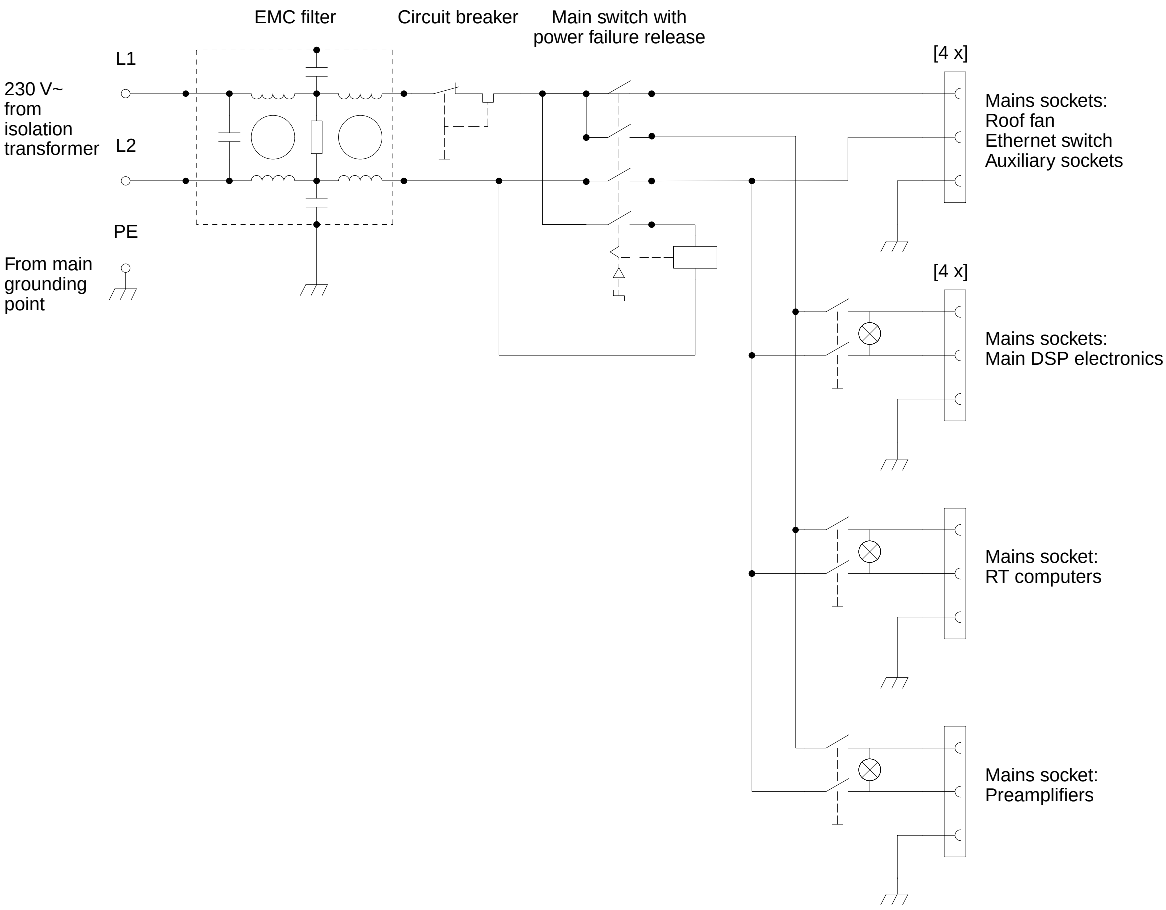


Figure A.7 Mains distribution in the main electronics cabinet

A.3 Power supplies

A.3.1 Schematic diagram

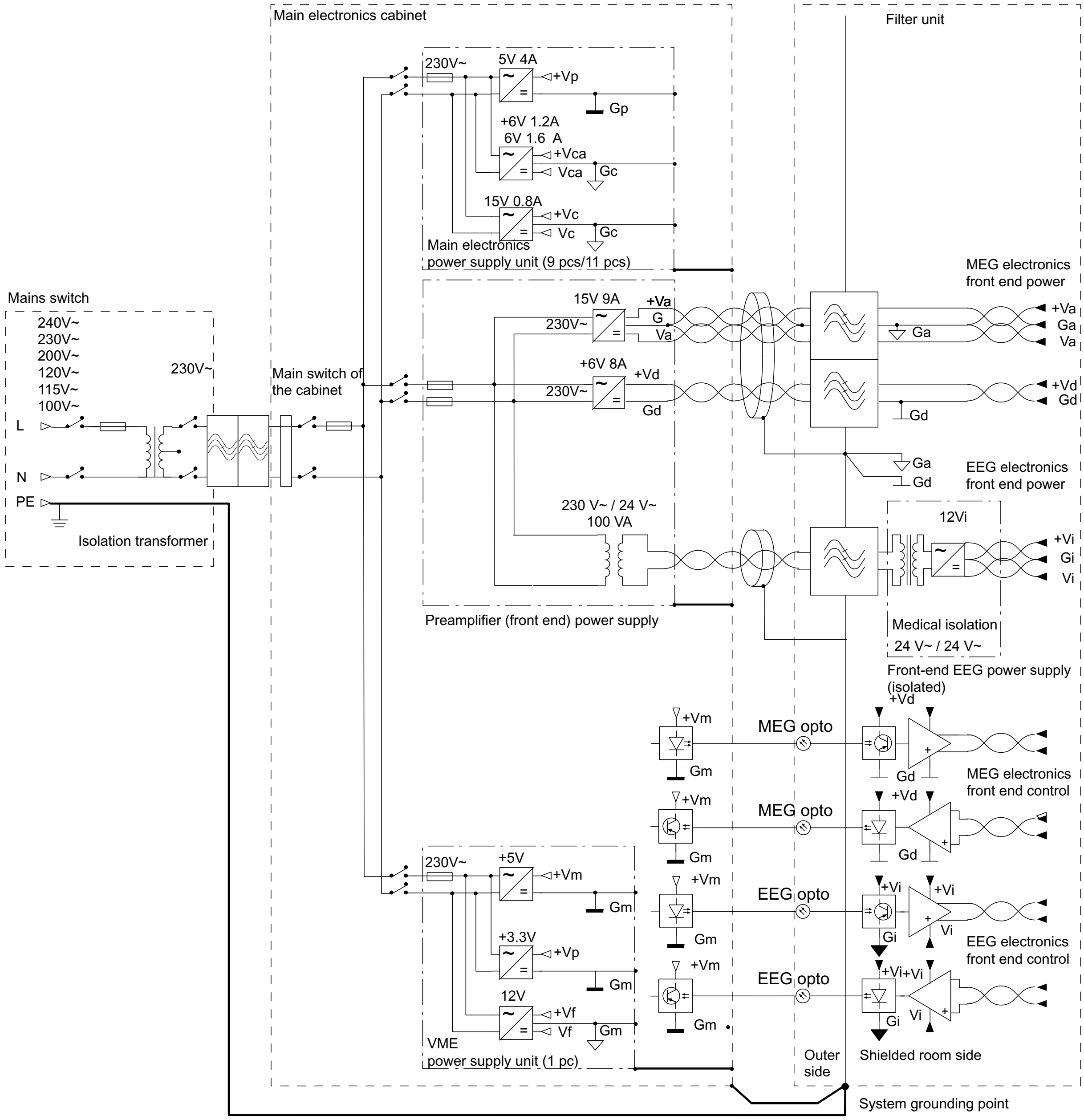
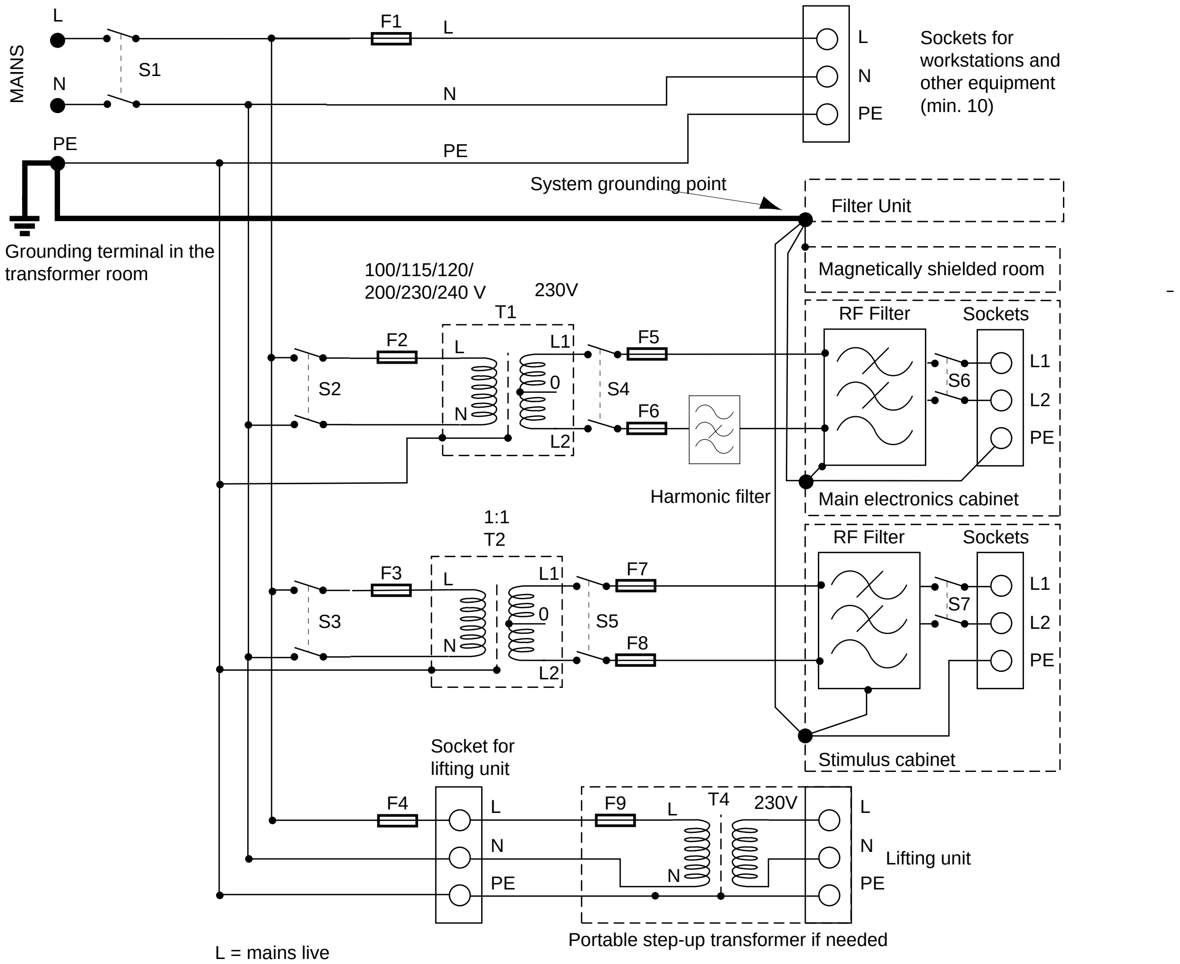


Figure A.8 Schematic diagram of power supplies. NOTE: The stimulus system is not shown.

A.3.2 Recommended power and grounding arrangement



L = mains live
N = mains neutral
PE = protective earth (ground)
L1 and L2 = isolated power terminals (symmetiric with respect to ground)
Switches S6 and S7 are inside cabinets (max. 10A)
Secondary fuses (F5-F8) and switches (S4, S5) are optional

Figure A.9 Recommended power and grounding arrangements. The specifications of the transformers, switches, and fuses are site-specific.

B

APPENDIX B

Fine calibrations of the He-level meter

The fine calibration of the helium level (He-level) meter needs to be done after the helium level meter board spare part has been changed or when the helium level meter's local display is not showing the correct helium level. The purpose of the calibration is to set the parameters of the helium level meter to show the right level values of the helium inside the dewar.

Note: The helium level inside the dewar needs to be less than 0 % before starting the calibration.

Special tool needed

- Helium level gauge calibration adapter (hereafter calibration adapter) for the helium level meter, part no. EL20377T.

Preparations

- The helium level inside the dewar needs to be below 0% (in the seated position), before the calibration according to this instruction can be started.
- The gantry must be moved into the seated position for the calibration.

Note: When the helium level meter's local display reading is 0%, there is still approximately 15 liters of helium left in the dewar.

Step-by-step instructions for calibration

1. Open the top covers of the probe unit to access the helium level meter board and the back cover of the probe unit (Figure B.1).
2. Switch off the power from the preamplifiers from the electronics cabinet.
3. Open the cover of the helium level meter board in the gantry.
4. Replace the helium level meter adapter board in Slot 27 on the top of the dewar with the calibration adapter.

5. Turn the switch of the calibration adapter to the “actual”position.

6. Switch on the power to the preamplifiers from the electronics cabinet.

   Note: Follow the recommended power on sequence.

7. Double-click the janitor icon in the Maintenance toolbox to start a session with the janitor program and type `pass homonculus122`.

8. Initialize the electronics with the `init` command.

9. Perform the `readreg meg 249 Id` command.

10. Janitor replies with a hexadecimal number (0xA4).

    If you get an error message, the program cannot contact the board. In that case, check the cabling.

11. Switch on the helium level meter’s local display (Figure B.2) on the side of the gantry and check that the lowest LED indicating an empty dewar is on.

12. Switch off the helium level meter’s local display.

13. Perform the `helium` command.

14. Janitor replies with the helium level reading in percents at the end of the text line.

15. Adjust the zero level potentiometer of the helium level meter board (in the gantry).

    The zero level potentiometer is marked with R55 (see Figure B.3). The goal is to adjust the potentiometer so that the helium level reading just changes from non-zero value to zero.

    a. Make a slight adjustment to R55.

    b. Perform the `helium` command.

    c. Janitor replies with the helium level.

    d. Repeat Steps a to c until the potentiometer setting is as close as possible to the position of the first non-zero reading (0.4%), but the meter is still showing zero.

16. Turn the calibration adapter switch to "full".

17. Adjust the full-level potentiometer of the helium level meter board (in the gantry) (Figure B.3).

The zero level potentiometer is marked with R56. The goal is to adjust the potentiometer so that the helium level reading just changes to 100 %.

a.Make a slight adjustment to R56.

b.Perform the `helium` command.

c.Janitor replies with the helium level.

d.Repeat Steps a - c in until the potentiometer setting is as close as possible to the position of the first reading below 100% (99.6%), but the meter is still showing 100%.

e.Then turn R56 a -turn clockwise.

18.Switch on the helium level meter's local display,

Now the helium level indicator LEDs should be all on (indicating 100% helium in this calibration mode).

19.Move the switch in the calibration board to the "actual" position.

20.Now the helium level meter's local display on the gantry and the janitor program should indicate that the helium level in the dewar is 0 %.

21.If the helium level readings were not 0% and 100% as explained in Steps 18 and 20, repeat Steps14 - 20.

22.The calibration has been completed, when the helium level is 0% and 100% in the janitor program and on the local helium level display.

23.Enter the `quit` command.

24.Switch off power from the preamplifiers in the electronics cabinet.

25.Remove the calibration adapter from the preamplifier position 27 and install the original adapter board.

26.Close the covers.

27.Power up the preamplifiers.

Note: Follow the recommended power on sequence.

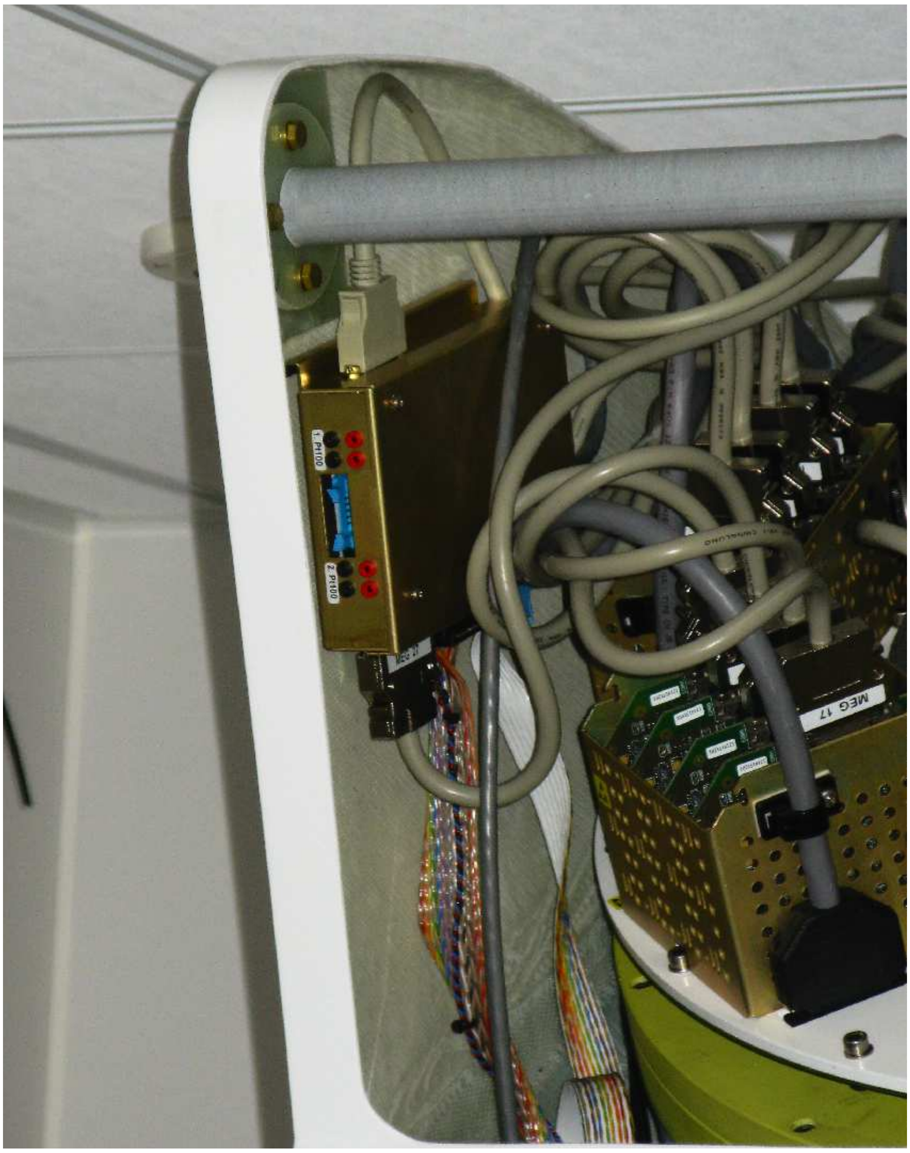


Figure B.1 He level meter board (with covers on) inside the gantry

Figure B.2 Helium level meter local display on the left side of the gantry

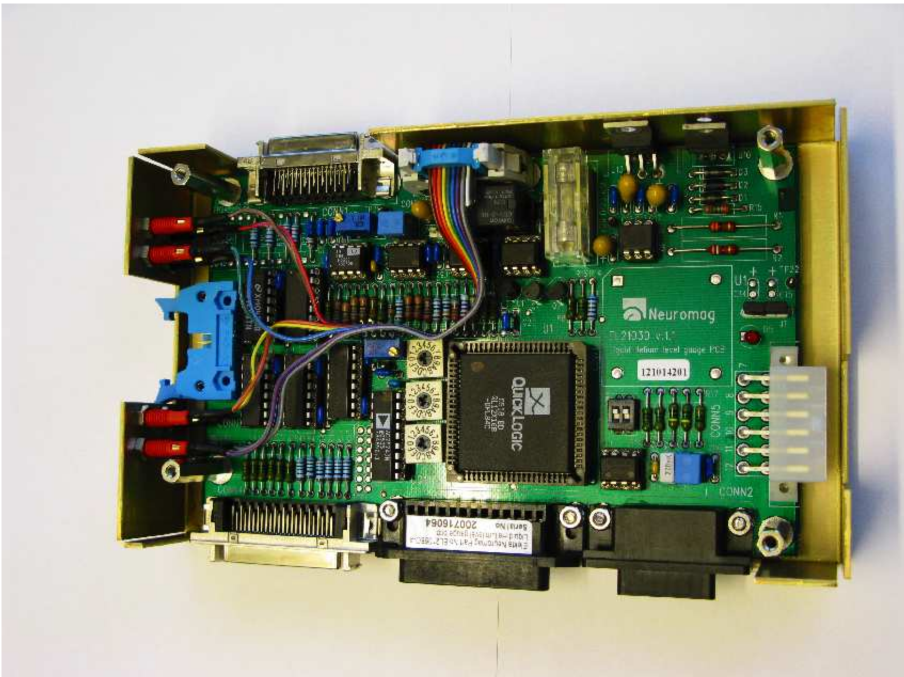


Figure B.3 Helium level meter board (covers removed), R56 is the upper adjustable potentiometer and R55 is the lower adjustable potentiometer, the board is in the ganty in this position