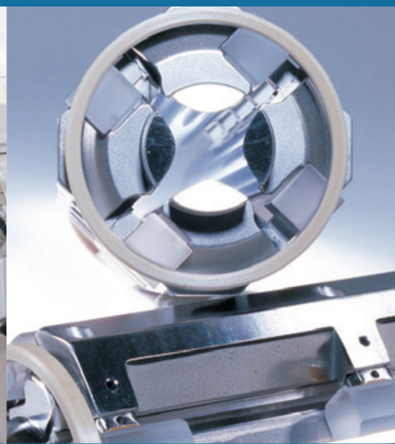
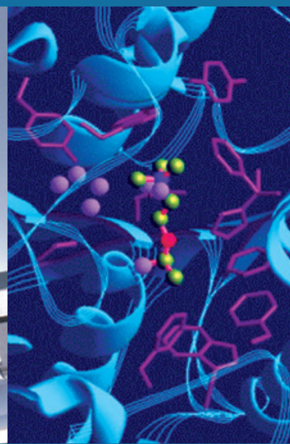
# LTQ Orbitrap™

## Hardware Manual

Revision A - 118 8330





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# Übereinstimmungserklärung gemäß EN 45014

Declaration of conformity according to EN 45014
Dichiarazione di conformità alla EN 45014

**Name des Herstellers:**
manufacturers name
nome produttore

Thermo Fisher Scientific

**Adresse des Herstellers:**
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**erklärt, dass das Produkt**
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# LTQ Orbitrap

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EMC (emissions)
EMC (emissioni)

EN 61000-6-3 Störemission (08.02)
EN 55022, Kl.B (09.03), EN 61000-3-2 (10.98),
EN 61000-3-3 (10.98)

**EMV (Störfestigkeit):**
EMC (immunity)
EMC (immunità)

EN 61000-6-2 Störfestigkeit (08.02),
EN 61000-4-2 (12.01), -3 (03.03), -4 (07.02), -5 (12.01), -6 (12.01),
-11 (12.01), EN 50204 (02.96)

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**Bremen, Germany, 11. Dezember 2006**

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# Read This First

Welcome to the Thermo Scientific, LTQ Orbitrap™ system! The LTQ Orbitrap is a member of the family of LTQ™ mass spectrometer (MS) hybrid instruments.

## Who uses this Guide

This *LTQ Orbitrap Hardware Manual* is intended for all personnel that need a thorough understanding of the instrument (to perform maintenance or troubleshooting, for example). This manual should be kept near the instrument to be available for quick reference.

## Scope of this Guide

This *LTQ Orbitrap Hardware Manual* contains a description of the modes of operation and principle hardware components of your LTQ Orbitrap instrument. In addition, this manual provides step-by-step instructions for cleaning and maintaining your instrument.

This manual includes the following chapters:

- Chapter 1: "Functional Description" describes the principal components of the LTQ Orbitrap.
- Chapter 2: "Basic System Operations" provides procedures for shutting down and starting up the LTQ Orbitrap.
- Chapter 3: "User Maintenance" outlines the maintenance procedures that you should perform on a regular basis to maintain optimum MS detector performance.
- Chapter 4: "Replaceable Parts" lists the replaceable parts for the MS detector and data system.

## Changes to the Manual

To suggest changes to this manual, please send your comments to:

Editors, Technical Documentation
Thermo Fisher Scientific
Hanna-Kunath-Str. 11

28199 Bremen

Germany

documentation.bremen@thermofisher.com

You are encouraged to report errors or omissions in the text or index. Thank you.

## Typographical Conventions

Typographical conventions have been established for Thermo Fisher Scientific manuals for the following:

- Data input
- Admonitions
- Topic headings

### Data Input

Throughout this manual, the following conventions indicate data input and output via the computer:

- Messages displayed on the screen are represented by capitalizing the initial letter of each word and by italicizing each word.
- Input that you enter by keyboard is identified by quotation marks: single quotes for single characters, double quotes for strings.
- For brevity, expressions such as “choose File > **Directories**” are used rather than “pull down the File menu and choose Directories.”
- Any command enclosed in angle brackets < > represents a single keystroke. For example, “press **<F1>**” means press the key labeled *F1*.
- Any command that requires pressing two or more keys simultaneously is shown with a plus sign connecting the keys. For example, “press **<Shift>** + **<F1>**” means press and hold the <Shift> key and then press the <F1> key.
- Any button that you click on the screen is represented in bold face letters. For example, “click on **Close**”.

## Admonitions

Admonitions contain information that is important, but not part of the main flow of text.

Admonitions can be of the following types:

- **Note** – information that can affect the quality of your data. In addition, notes often contain information that you might need if you are having trouble.
- **Caution** – information necessary to protect your instrument from damage.
- **Warning** – hazards to human beings. Each Warning is accompanied by a Warning symbol.

## Topic Headings

The following headings are used to show the organization of topics within a chapter:

# Chapter Name

The following headings appear in the left column of each page:

## Second Level Topics

### Third Level Topics

#### Fourth Level Topics

## Safety and EMC Information

In accordance with our commitment to customer service and safety, this instrument has satisfied the requirements for the European CE Mark including the Low Voltage Directive.

Designed, manufactured and tested in an ISO9001 registered facility, this instrument has been shipped to you from our manufacturing facility in a safe condition.

**Caution** This instrument must be used as described in this manual. Any use of this instrument in a manner other than described here may result in instrument damage and/or operator injury. ▲

## Identifying Safety Information

The *LTQ Orbitrap Hardware Manual* contains precautionary statements that can prevent personal injury, instrument damage, and loss of data if properly followed. Warning symbols alert the user to check for hazardous conditions. These appear throughout the manual, where applicable, and are defined in Table i.

Table i. Warning Symbols

| Symbol | Description |
|---|---|
|  | **General** This general symbol indicates that a hazard is present, which if not avoided, could result in injuries.<br><br>The source of danger is described in the accompanying text. ▲ |
|  | **Electric Shock** High voltages capable of causing personal injury are used in the instrument. The instrument must be shut down and disconnected from line power before service or repair work is performed. ▲ |
|  | **Noxious** This symbol alerts to hazards resulting from noxious fumes. ▲ |
|  | **Hot Surface / Heat** Treat heated zones with respect. Allow heated components to cool down before servicing them! ▲ |

## Instrument-Specific Hazards

Every instrument has specific hazards, so be sure to read and comply with the following precautions. They will help ensure the safe, long-term use of your system.

1. Before plugging in any of the instrument modules or turning on the power, always make sure that the voltage and fuses are set appropriately for your local line voltage.

2. Only use fuses of the type and current rating specified. Do not use repaired fuses and do not short-circuit the fuse holder.

3. The supplied power cord must be inserted into a power outlet with a protective earth contact (ground). When using an extension cord, make sure that the cord also has an earth contact.

4. Do not change the external or internal grounding connections. Tampering with or disconnecting these connections could endanger you and/or damage the system.

**Caution** The instrument is properly grounded in accordance with regulations when shipped. You do not need to make any changes to the electrical connections or to the instrument's chassis to ensure safe operation. ▲

5. Never run the system without the housing on. Permanent damage can occur.

6. Do not turn the instrument on if you suspect that it has incurred any kind of electrical damage. Instead, disconnect the power cord and contact a Service Representative for a product evaluation. Do not attempt to use the instrument until it has been evaluated. (Electrical damage may have occurred if the system shows visible signs of damage, or has been transported under severe stress.)

7. Damage can also result if the instrument is stored for prolonged periods under unfavorable conditions (e.g., subjected to heat, water, etc.).

8. Always disconnect the power cord before attempting any type of maintenance.

9. Capacitors inside the instrument may still be charged even if the instrument is turned off.

10. Never try to repair or replace any component of the system that is not described in this manual without the assistance of your service representative.

## Safety Advice for Possible Contamination

**Hazardous Material Might Contaminate Certain Parts of Your System During Analysis.**

In order to protect our employees, we ask you to adhere to special precautions when returning parts for exchange or repair.

If hazardous materials have contaminated mass spectrometer parts, Thermo Fisher Scientific can only accept these parts for repair if they have been properly decontaminated. Materials, which due to their structure and the applied concentration might be toxic or which in publications are reported to be toxic, are regarded as hazardous. Materials that will generate synergetic hazardous effects in combination with other present materials are also considered hazardous.

Your signature on the **Repair-Covering letter** confirms that the returned parts have been decontaminated and are free of hazardous materials.

The Repair-Covering letter can be ordered from your service engineer or downloaded from the **Customer Information Service** (**CIS**) site. Please register under http://register.thermo-bremen.com/form/cis.

Parts contaminated by radioisotopes are not subject to return to Thermo Fisher Scientific – either under warranty or the exchange part program. If parts of the system may be possibly contaminated by hazardous material, please make sure the Field engineer is informed before the engineer starts working on the system.

# Contents

# Figures

# Tables

# Chapter 1 Functional Description

This chapter provides an overview of the functional elements of the LTQ Orbitrap. It contains the following topics:

## General Description

LTQ Orbitrap is a hybrid mass spectrometer incorporating the LTQ XL™ linear trap and the Orbitrap™. Figure 1-1 shows a front view of the instrument.


**Figure 1-1.** LTQ Orbitrap front view

Figure 1-2 on page 1-3 shows the schematic view of the LTQ Orbitrap. The LTQ Orbitrap consists of three main components, which are described in the following topics:

- A linear ion trap (Thermo Scientific LTQ XL) for sample ionization, selection, fragmentation, and AGC™.
- An intermediate storage device (curved linear trap) that is required for short pulse injection, and
- An Orbitrap analyzer for Fourier based analysis

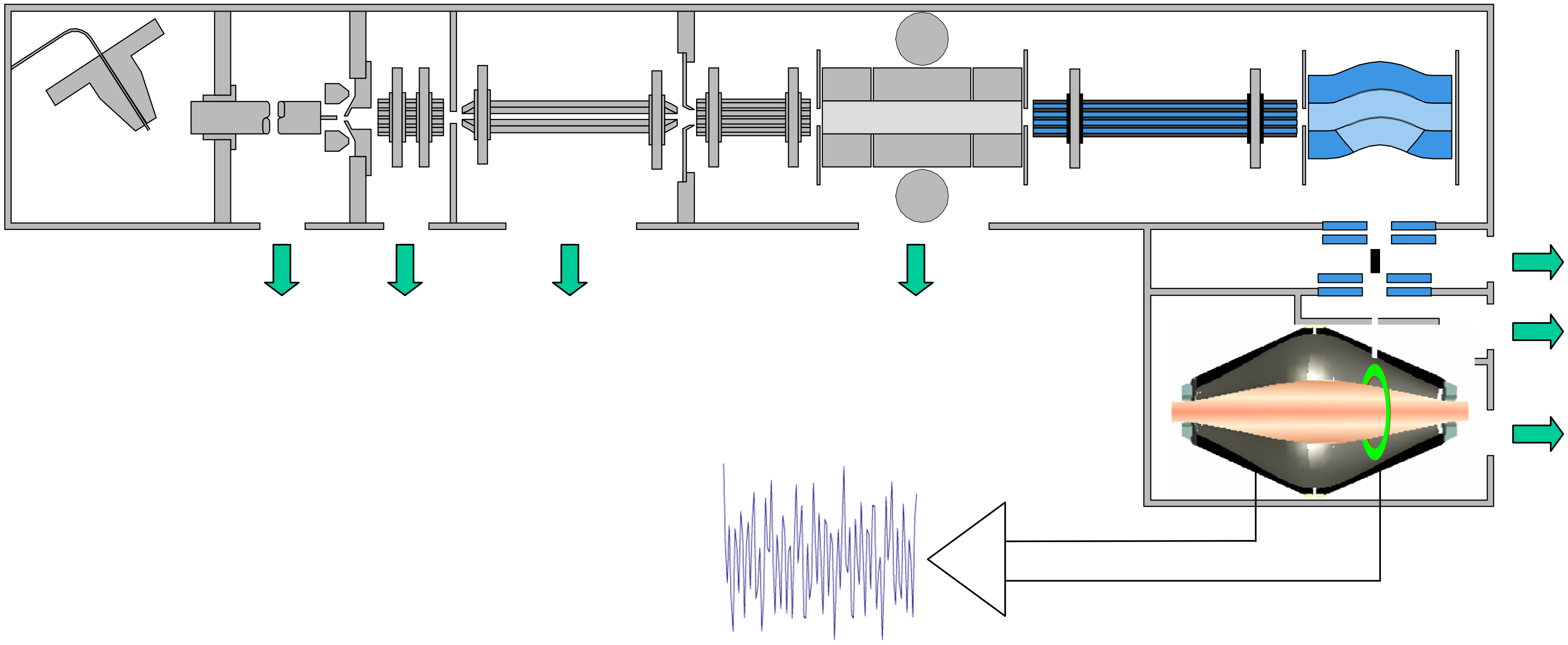

**Figure 1-2.** Schematic view of the LTQ Orbitrap

Wheels at the bottom side of the instrument facilitate positioning the LTQ Orbitrap at the intended place in the laboratory. The instrument is designed to be placed with its rear panel against a wall. To ensure a sufficient air flow for cooling the instrument, spacers on the rear panel provide for minimum distance to the wall.

The mains inlet as well as power outlets for recirculating chiller and data system are located at the right side (looking from the front). Rotary pumps are hidden under the linear trap and accessible from the front. The left side panel and the front panel are mounted on hinges and the right side panel is removable.

The top lid opens upwards to allow easy access for Field Engineers from the top. See Figure 1-3.

**Figure 1-3.** Top lid opened

A stand-alone recirculating water chiller is delivered with the instrument. It is connected to the right side of the instrument.

## Specifications

The LTQ Orbitrap has the following measuring properties:

| | |
|---|---|
| **Resolution (apodized)** | 60000 (FWHM) @ m/z 400<br>with a scan repetition rate of 1 second<br>Minimum resolution 7500,<br>maximum resolution 100000 @ m/z 400 |
| **Cycle Time** | 1 scan at 60000 resolution @ m/z 400 per second |
| **Mass Range** | m/z 50–2000; m/z 200–4000 |
| **Mass Accuracy** | <5 ppm RMS for 8 h period with external calibration,<br><2 ppm RMS with internal calibration |
| **Dynamic Range** | >10000 between mass spectra,<br>>4000 between highest and lowest detectable mass in one spectrum |
| **MS/MS** | MS/MS and $MS^n$ scan functions |

## Control Elements

The LTQ Orbitrap MS detector is mainly operated from the desktop computer (data system). Some control elements for important system functions are located directly on the instrument. They are described in the following sections.

### System Status LEDs

Figure 1-4 shows the system status LEDs at the front of the instrument. Five LEDs indicate the main functions of the system. (See also Figure 1-5 on page 1-7.) While the Power LED is directly controlled by the 3 × 230 V input, all other LEDs are controlled by the power distribution board. (Refer to topic "Power Distribution Board" on page 1-36.) Table 1-1 explains the function of the various LEDs.

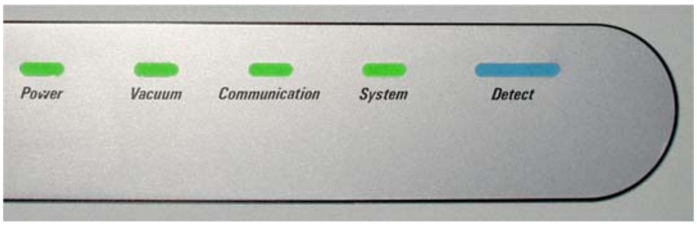


**Figure 1-4.** System status LEDs

The system status LEDs at the front panel of the linear ion trap are described in the *LTQ XL Hardware Manual*.

**Table 1-1.** System status LEDs of the LTQ Orbitrap

| LED | Status | Information |
|---|---|---|
| Power | Green | Main switch on |
| | Off | Main switch off |
| Vacuum* | Green | Operating vacuum reached |
| | Yellow | Insufficient vacuum or Vacuum Pumps switch off |
| Communication | Green | Communication link between instrument and data system established |
| | Yellow | Communication link starting up or Vacuum Pumps switch off |
| System* | Green | System ready |
| | Yellow | FT Electronics switch off or Vacuum Pumps switch off |
| Detect | Blue | Instrument is scanning |
| | Off | Instrument is not scanning |

*These LEDs are flashing when a system bakeout is performed. See topic "Baking Out the System" on page 3-4.

## Control Panels

Figure 1-5 shows the right side of the LTQ Orbitrap. Located here are the control panels, switches, and the ports for the external connections (mains supply, gases, Ethernet communication, and cooling water).

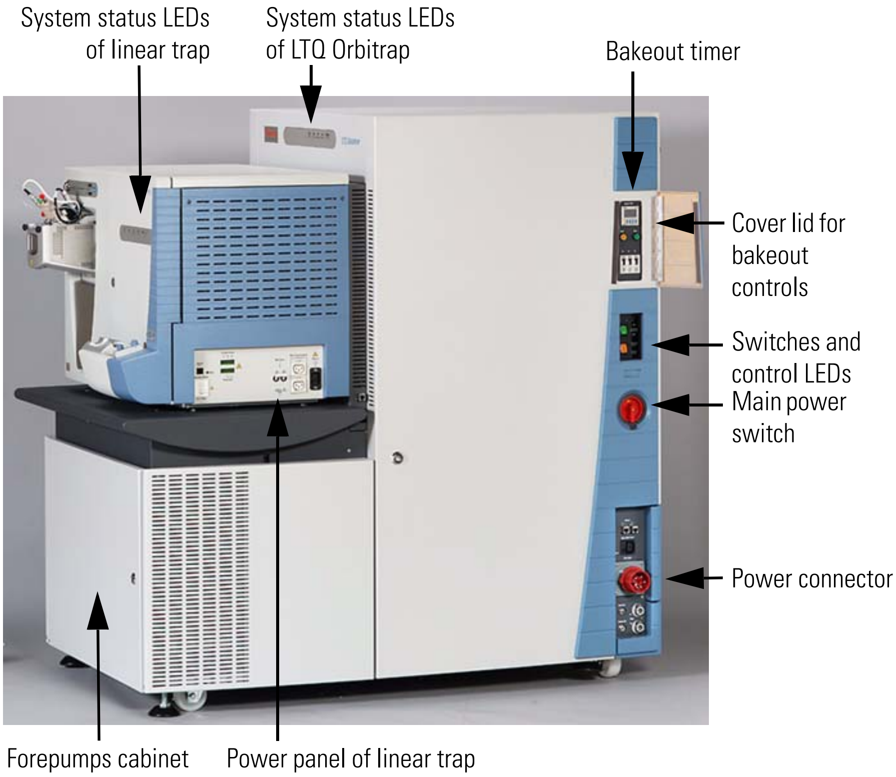


**Figure 1-5.** Right side of the LTQ Orbitrap

For more information about the external connections, refer to topic "External Connections" on page 1-10.

### Upper Control Panel

The upper instrument control panel comprises the bakeout timer, the bakeout control buttons, and three circuit breakers. To access the upper control panel, swing open the small lid (opens from left to right). See Figure 1-5 and Figure 1-6 on page 1-8.

The timer allows setting the duration for the bakeout of the system. After the duration is set, the bakeout procedure is started by pressing the green button on the right. A running bakeout procedure can be stopped by pressing the orange button on the left side. For instructions about performing a bakeout, refer to topic "Baking Out the System" on page 3-4.

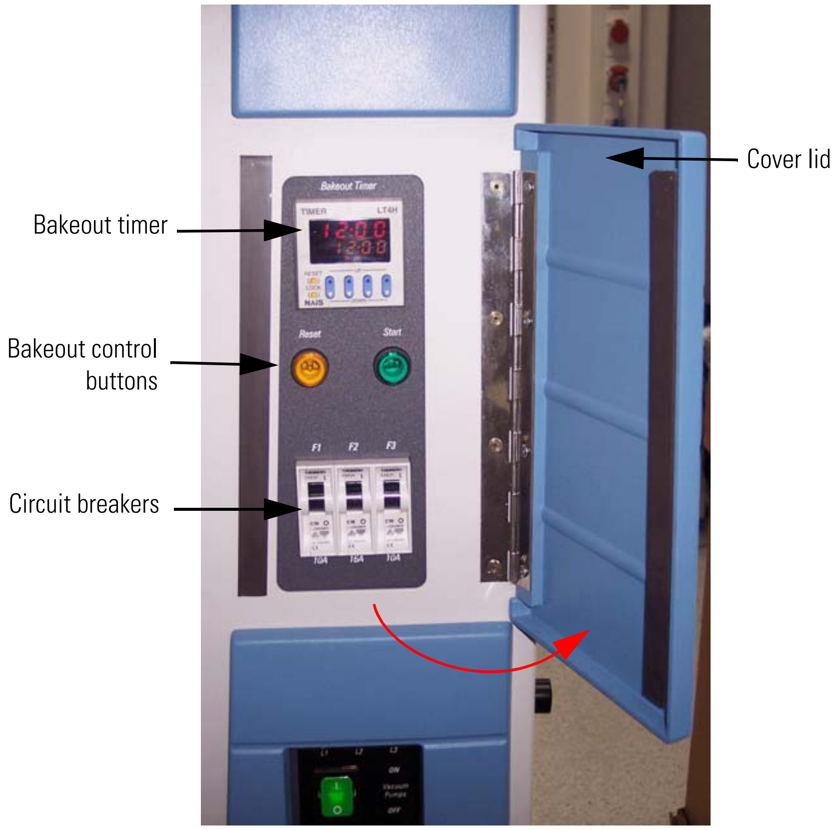


**Figure 1-6.** Upper control panel

**Note** The buttons themselves have no indicator function. A running bakeout procedure is indicated by flashing Vacuum and System LEDs at the front side of the instrument. See Figure 1-4 on page 1-6. ▲

Three circuit breakers are located at the bottom of this control panel. Table 1-2 shows the parts of the LTQ Orbitrap that are protected by the respective circuit breaker. The proper function of each circuit breaker is signaled by a dedicated LED in the power control panel (e.g. F1 corresponds to L1).

**Table 1-2.** Circuit breakers of the LTQ Orbitrap

| Circuit breaker | Ampere | LED | Instrument parts |
|---|---|---|---|
| F1 | 10 | L1 | Power Distribution |
| F2 | 16 | L2 | Linear ion trap |
| F3 | 10 | L3 | Multiple socket outlets (Recirculating chiller, data system, LC, heater, etc) |

## Power Control Panel

In addition to the system status LEDs at the front side (see Figure 1-4 on page 1-6), the LTQ Orbitrap MS instrument has three power control LEDs above the Vacuum Pumps switch at the right side. See

Figure 1-7. They indicate whether the corresponding circuit breaker is closed and the respective parts of the instrument have power. (See Table 1-2 on page 1-8.)

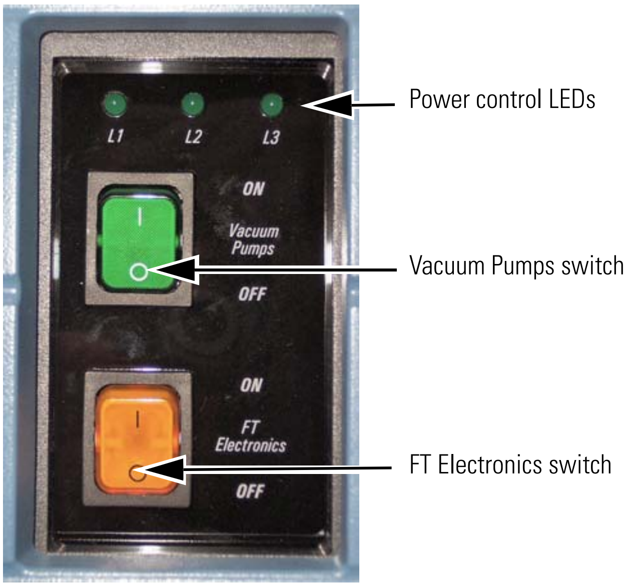


**Figure 1-7.** Power control panel with power control LEDs and switches

The use of the switches below the power control LEDs changes the working mode of the power distribution. (See topic "Working Modes of the Power Distribution" on page 1-48.)

The Vacuum Pumps switch can be set into the positions **ON** or **OFF**. When the switch is in the **OFF** position, everything but the multiple socket outlet is switched off.

The FT Electronics switch can be set into the Operating position (**ON**) or into the Service position (**OFF**). When the switch is in the Service position, all components are switched off with exception of the following:

- Fans
- Heater control
- Power distribution (Refer to the topic "Power Distribution Board" on page 1-36)
- Pumps (Refer to the topic "Vacuum System" on page 1-18)
- Temperature controller (Refer to the topic "Temperature Controller Board" on page 1-45)
- Vacuum control

The linear ion trap also remains on because it has a separate Service switch.

## Main Power Switch

The main power switch must be turned 90° clockwise/anti-clockwise to switch on/off the instrument (see Figure 1-8). Placing the main power switch in the Off position turns off all power to the LTQ Orbitrap MS instrument (and linear ion trap as well, including the vacuum pumps).

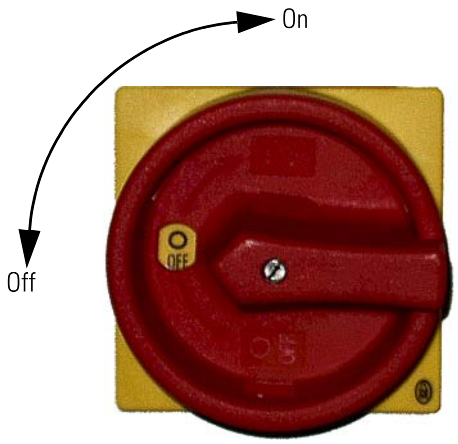


**Figure 1-8.** Main power switch

**Note** When the main power switch is in the Off position, you can secure it with a padlock or a cable tie (to prevent unintended re-powering when performing maintenance, for example). ▲

## External Connections

Figure 1-9 on page 1-11 shows the lower right side of the instrument with the external connections for mains supply, gases, cooling water, and Ethernet communication.

The power connector for the mains supply is located on the center. The cooling water ports are located below the power connector. (See also topic "Cooling Water Circuit" on page 1-25.) A Teflon® hose connects the instrument to the nitrogen gas supply. Metal tubing connects the instrument with the helium gas supply. (See also topic "Gas Supply" on page 1-23.) Located at the top are two ports for Ethernet cables for connecting the LTQ Orbitrap and the linear ion trap via an Ethernet hub with the data system computer.

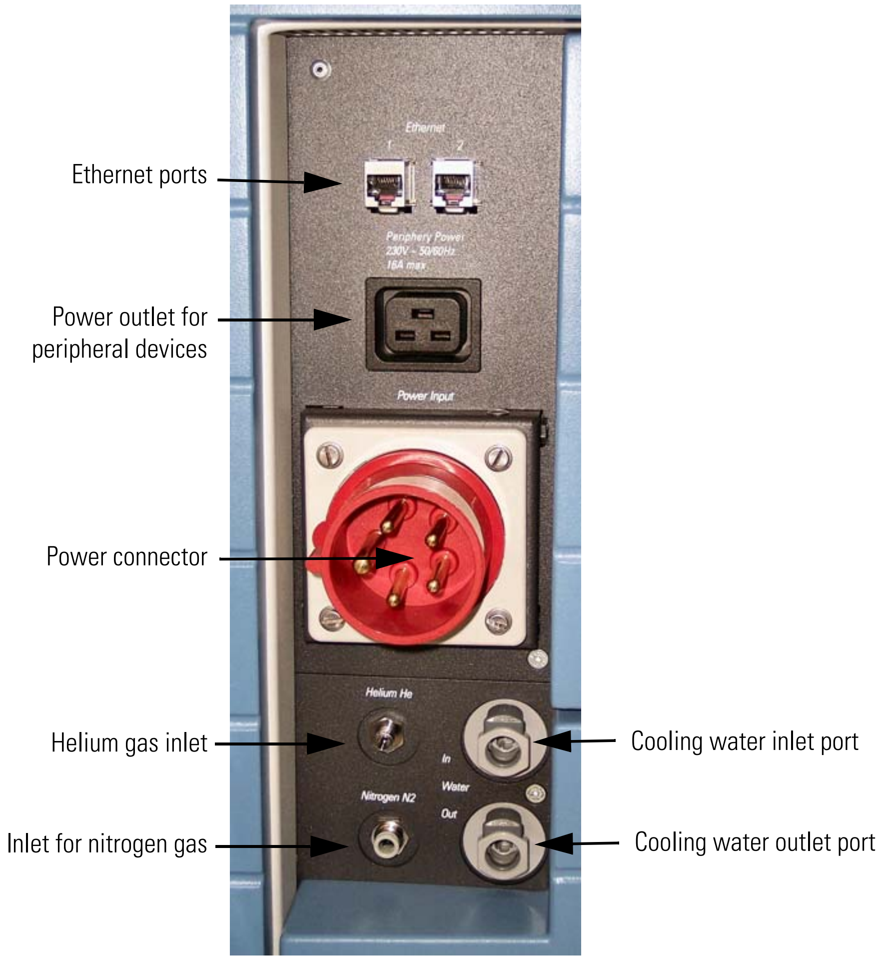


**Figure 1-9.** External connections to the LTQ Orbitrap

The exhaust hose from the rotary pumps is led backwards below the instrument, comes out the back of the instrument, and connects the pumps to the exhaust system in the laboratory.

The power outlet for peripheral devices (recirculating chiller and data system) is located above the mains supply port. The outlet provides the mains supply for the peripherals via a multiple socket outlet.

## Linear Ion Trap

The LTQ Orbitrap system can utilize a variety of ionization techniques such as ESI, APCI, or APPI. Maintenance of the API source, as well as switching between ionization methods, is vent-free. Ions are transferred by octapole and “square” quadrupole lenses into an ion trap that is optimized for axial ion ejection into the curved linear trap. (See Figure 1-2 on page 1-3.)

The linear ion trap is an independent MS detector (Thermo Scientific LTQ XL), which can store, isolate, and fragment ions and then send them either to the Orbitrap for further analysis or to an SEM detector. The linear ion trap is a unique ion preparation and injection system for Orbitrap MS, because it has greater ion storage capacity than conventional 3D ion trap devices. The linear ion trap is completely described in the *LTQ XL Hardware Manual*.

All the ion handling, selection and excitation capabilities of the ion trap can be used to prepare ions for analysis in the Orbitrap. These features include storage and ejection of all ions, storage of selected masses or mass ranges, as well as ion isolation. Isolated ions can be excited and then fragmented as necessary for MS/MS and MSn experiments. The patented Automatic Gain Control (AGC) provides extended dynamic range and insures optimized overall performance of the ion trap and Orbitrap MS.

The linear ion trap and the transfer chamber are mounted on a table. See Figure 1-1 on page 1-2. The table also serves as a housing for the forepumps. See Figure 1-17 on page 1-20. The LTQ Orbitrap provides power for the linear ion trap – and for the recirculating chiller and data system.

The linear ion trap is delivered with power connector, gas lines (He and $N_2$), and vacuum tube lines extending to the ESI source. On the rear side of the LTQ XL ion trap is a flange with an O-ring seal. When the flange is removed, the Orbitrap transfer chamber is mounted to the flange of the linear ion trap. The transfer chamber is held with supports on the table. The components of the ion optics and the Orbitrap are fixed to the transfer chamber.

## Orbitrap Analyzer

This section describes the basic principle of the Orbitrap analyzer. The heart of the system is an axially-symmetrical mass analyzer. It consists of a spindle-shape central electrode surrounded by a pair of bell-shaped outer electrodes. See Figure 1-10. The Orbitrap employs electric fields to capture and confine ions.

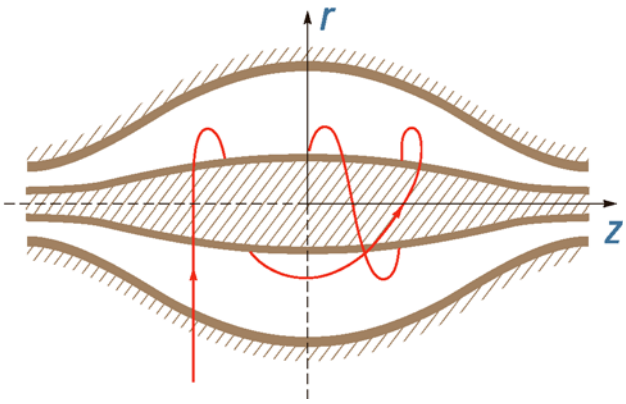


**Figure 1-10.** Schematic view of the Orbitrap cell and example of a stable ion trajectory

## Measuring Principle

In the mass analyzer shown in Figure 1-10, stable ion trajectories rotate around an axial central electrode with harmonic oscillations along it. The frequency ω of these harmonic oscillations along the z-axis depends only on the ion mass-to-charge ratio *m/q* and the instrumental constant *k*:

$$w = \sqrt{\frac{q}{m} \times k}$$

Two split halves of the outer electrode of the Orbitrap detect the image current produced by the oscillating ions. By Fast Fourier Transformation (FFT) of the image current, the instrument obtains the frequencies of these axial oscillations and therefore the mass-to-charge ratios of the ions.

## Curved Linear Trap

On their way from the linear trap to the Orbitrap, ions move through the gas-free RF octapole (Oct 1) into the gas-filled curved linear trap (C-Trap). See Figure 1-11 on page 1-14. Ions in the C-Trap are returned by the trap electrode. Upon their passage, the ions loose enough kinetic energy to prevent them from leaving the C-Trap through the Gate. The nitrogen collision gas (bath gas) is used for dissipating the kinetic energy of ions injected from the LTQ XL and for cooling them down to the axis of the curved linear trap.

Voltages on the end apertures of the curved trap (Trap and Gate apertures) are elevated to provide a potential well along its axis. These voltages may be later ramped up to squeeze ions into a shorter thread along this axis. The RF to the C-Trap ("Main RF") is provided by the CLT RF main board. (See page 1-46.) Trap and gate DC voltages as well as RF voltages to octapole 1 are all provided by the ion optic supply board. (See page 1-42.) High voltages to the lenses are provided by the high voltage power supply board. (See page 1-49.)

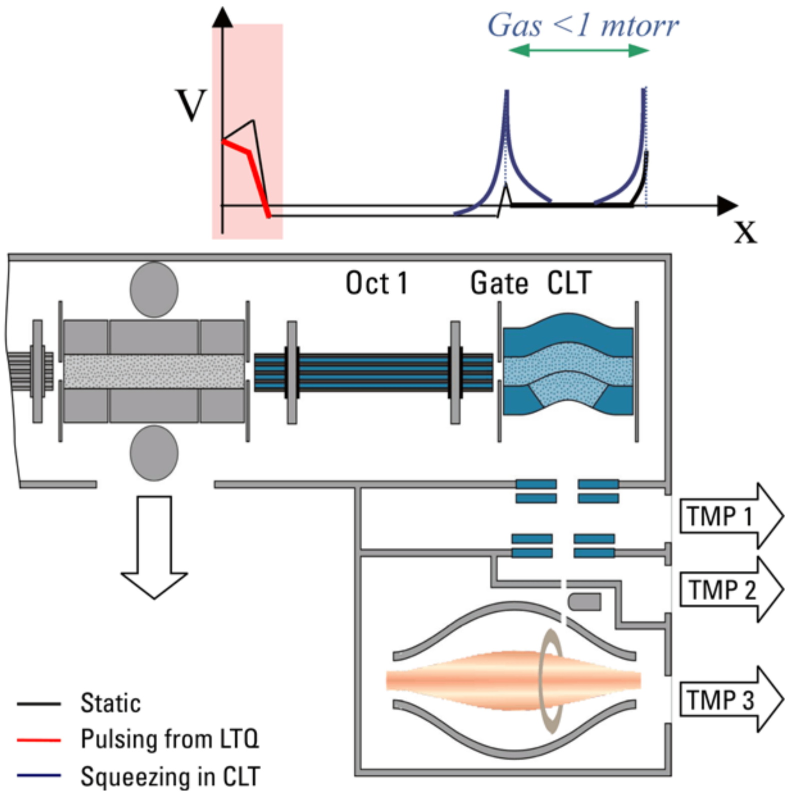


**Figure 1-11.** Layout of the instrument, also showing the applied voltages

## Extraction of Ion Packets

For ion extraction, the RF on the rods of the C-Trap is switched off and extracting voltage pulses are applied to the electrodes, pushing ions orthogonally to the curved axis through a slot in the inner hyperbolic electrode. Because of the initial curvature of the curved trap and the subsequent lenses, the ion beam converges on the entrance into the Orbitrap. The lenses form also differential pumping slots and cause spatial focusing of the ion beam into the entrance of the Orbitrap. Ions are electrostatically deflected away from the gas jet, thereby eliminating gas carryover into the Orbitrap.

Owing to the fast pulsing of ions from the curved trap, ions of each mass-to-charge ratio arrive at the entrance of the Orbitrap as short packets only a few millimeters long. For each mass/charge population, this corresponds to a spread of flight times of only a few hundred nanoseconds for mass-to-charge ratios of a few hundred Daltons/charge.

Such durations are considerably shorter than a half-period of axial ion oscillation in the trap. When ions are injected into the Orbitrap at a position offset from its equator (Figure 1-12), these packets start coherent axial oscillations without the need for any additional excitation cycle.

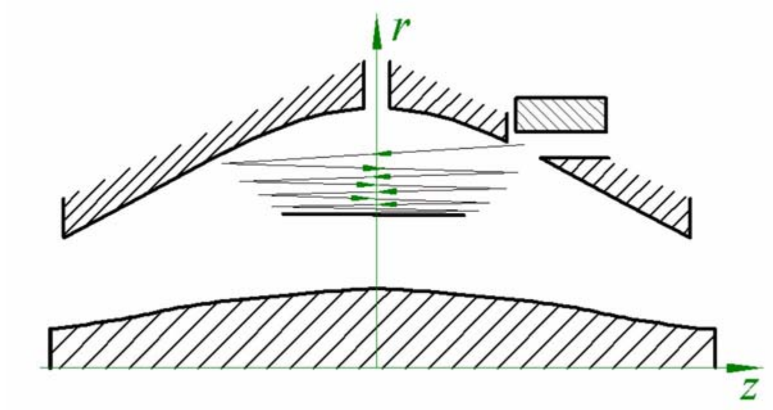


**Figure 1-12.** Principle of electrodynamic squeezing of ions in the Orbitrap as the field strength is increased

The evolution of an ion packet during the increase of the electric field is shown schematically on Figure 1-12. When the injected ions approach the opposite electrode for the first time, the increased electric field (owing to the change of the voltage on the central electrode) contracts the radius of the ion cloud by a few percent. The applied voltages are adjusted to prevent collision of the ions with the electrode. A further increase of the field continues to squeeze the trajectory closer to the axis, meanwhile allowing for newly arriving ions (normally, with higher *m/q*) to enter the trap as well. After ions of all *m/q* have entered the Orbitrap and moved far enough from the outer electrodes, the voltage on the central electrode is kept constant and image current detection takes place.

## Ion Detection

During ion detection, both the central electrode and deflector are maintained at very stable voltages so that no mass drift can take place. The outer electrode is split in half at $z$=0, allowing the ion image current in the axial direction to be collected. The image current on each of half of the outer electrode is differentially amplified and then undergoes analog-to-digital conversion before processing using the fast Fourier transform algorithm.

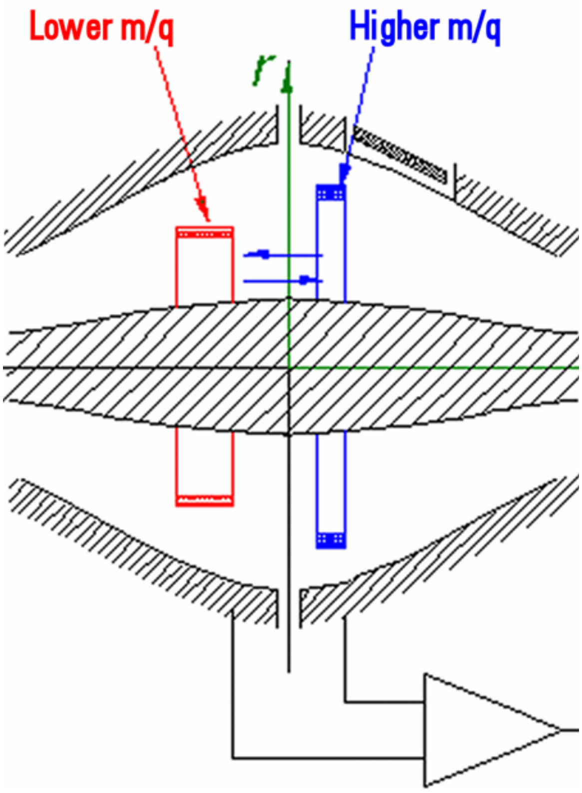


**Figure 1-13.** Approximate shape of ion packets of different m/q after stabilization of voltages

As mentioned above, stable ion trajectories within the Orbitrap combine axial oscillations along the z-axis with rotation around the central electrode and vibrations in the radial direction. (See Figure 1-10 on page 1-13.) For any given *m/q*, only the frequency of axial oscillations is completely independent of initial ion parameters, while rotational and radial frequencies exhibit strong dependence on initial radius and energy. Therefore, ions of the same mass/charge ratio continue to oscillate along *z* together, remaining in-phase for many thousands of oscillations.

In contrast to the axial oscillations, the frequencies of radial and rotational motion will vary for ions with slightly different initial parameters. This means that in the radial direction, ions dephase orders of magnitude faster than in the axial direction, and the process occurs in a period of only 50–100 oscillations. After this, the ion packet of a given *m/q* assumes the shape of a thin ring, with ions uniformly distributed along its circumference. (See Figure 1-13.) Because of this angular and radial smearing, radial and rotational frequencies cannot appear in the measured spectrum. Meanwhile, axial oscillations will persist, with axial thickness of the ion ring remaining small compared with the axial amplitude. Moving from one half outer electrode to the other, this ring will induce opposite currents on these halves, thus creating a signal to be detected by differential amplification.

## Active Temperature Control

Active temperature control is achieved by monitoring temperature directly on the Orbitrap assembly and compensating any changes in ambient temperature by a thermoelectric cooler (Peltier element) on the outside of the UHV chamber. A dedicated temperature controller board is used for this purpose. See page 1-45.

### Peltier Cooling

To allow stable operating conditions in the UHV chamber, it can be cooled or heated (outgassing) by means of a Peltier element located on the outside. A second Peltier element is located on the back of the CE power supply board. See Figure 1-30 on page 1-42.

The Peltier cooling is based on the Peltier Effect, which describes the effect by which the passage of an electric current through a junction of two dissimilar materials (thermoelectric materials) causes temperature differential (cooling effect). The voltage drives the heat to flow from one side of the Peltier element to the other side, resulting in cooling effects on one side and heating effects on the other side.

To remove the heat from the hot side of the Peltier elements, they are connected to the cooling water circuit of the LTQ Orbitrap MS instrument. See topic "Cooling Water Circuit" on page 1-25 for further information.

## Vacuum System

Figure 1-14 shows a schematic overview of the vacuum system. The Orbitrap has the following vacuum compartments:

- **CLT compartment in the aluminum vacuum chamber** (pumped by the same pump as the linear trap)
- **Vacuum chamber** (pumped by a water-cooled 60 L/s – for $N_2$ – turbopump TMH 071, TMP 1, manufacturer: Pfeiffer)
- **Ultra high vacuum chamber** (UHV chamber, pumped by a water-cooled 60 L/s turbopump TMH 071, TMP 2, manufacturer: Pfeiffer)
- **Orbitrap chamber** (pumped by a 210 L/s – for $N_2$ – water-cooled turbopump TMU 262, TMP 3, manufacturer: Pfeiffer)

The forepumps of the linear trap provide the forevacuum for the turbopumps.

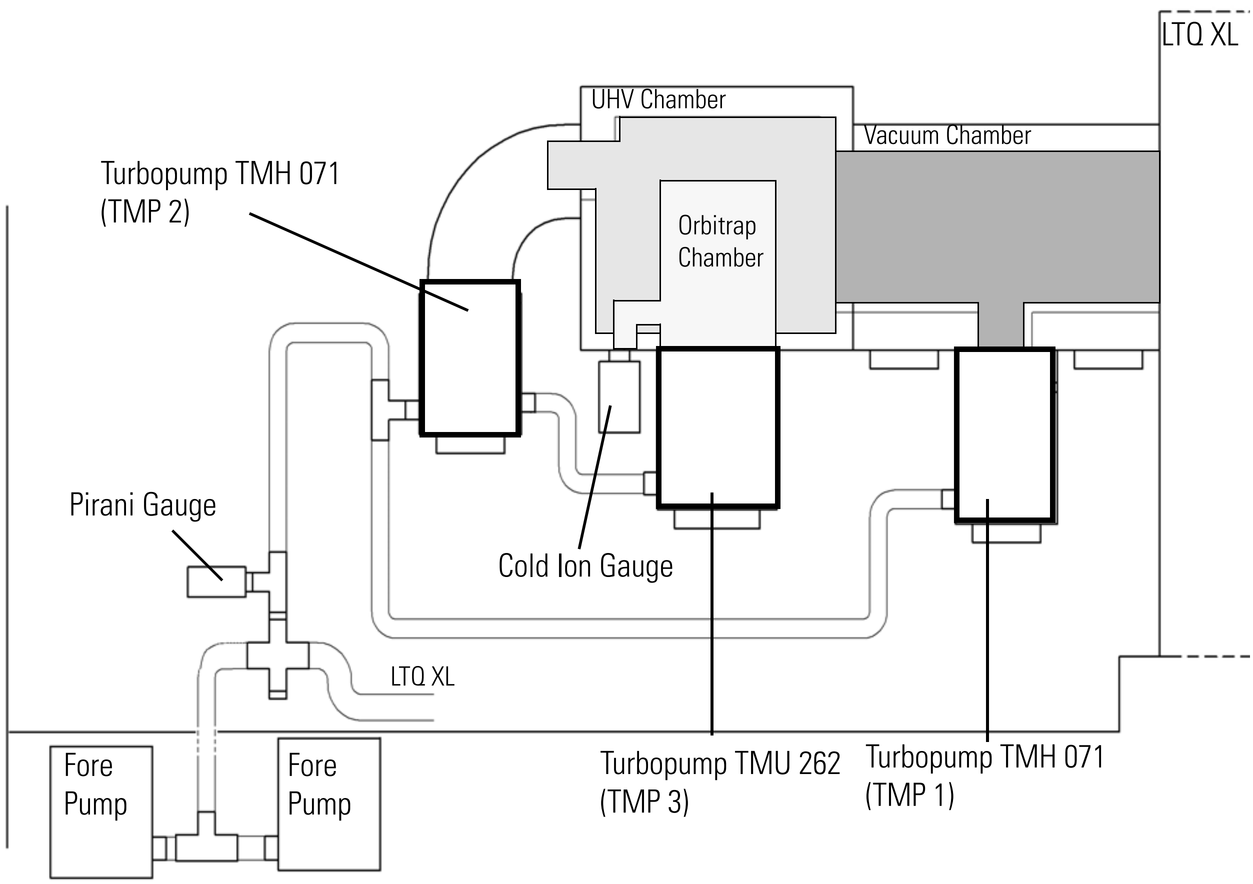


**Figure 1-14.** Schematical view of vacuum system (CLT compartment not shown)

## Turbopumps

All parts of the system except for the Orbitrap analyzer are mounted in a aluminum vacuum chamber evacuated by a 60 L/s turbopump (TMP 1, see Figure 1-15). The rotary vane pumps of the linear trap (see below) provide the forevacuum for this pump. This chamber is bolted to a stainless steel welded UHV chamber housing the Orbitrap, lenses, and corresponding electrical connections.

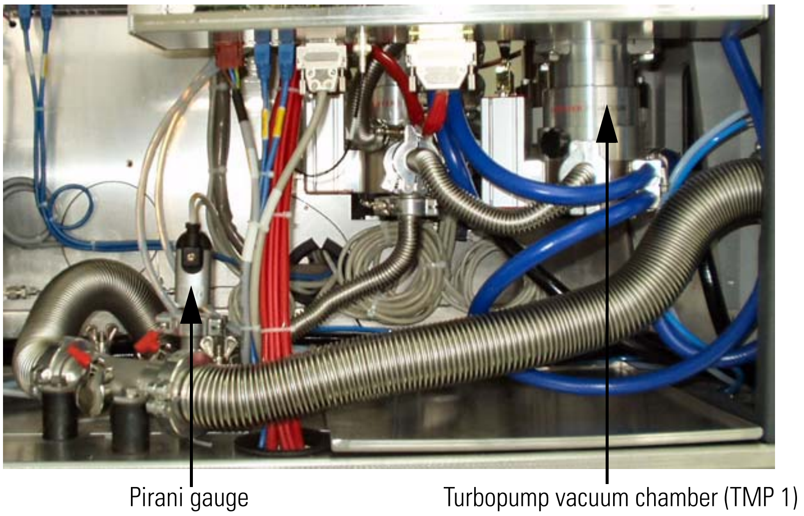


**Figure 1-15.** Vacuum components on the left instrument side

The UHV chamber is evacuated down to $10^{-8}$ mbar pressure range by a 60 L/s UHV turbopump (TMP 2, see Figure 1-16).

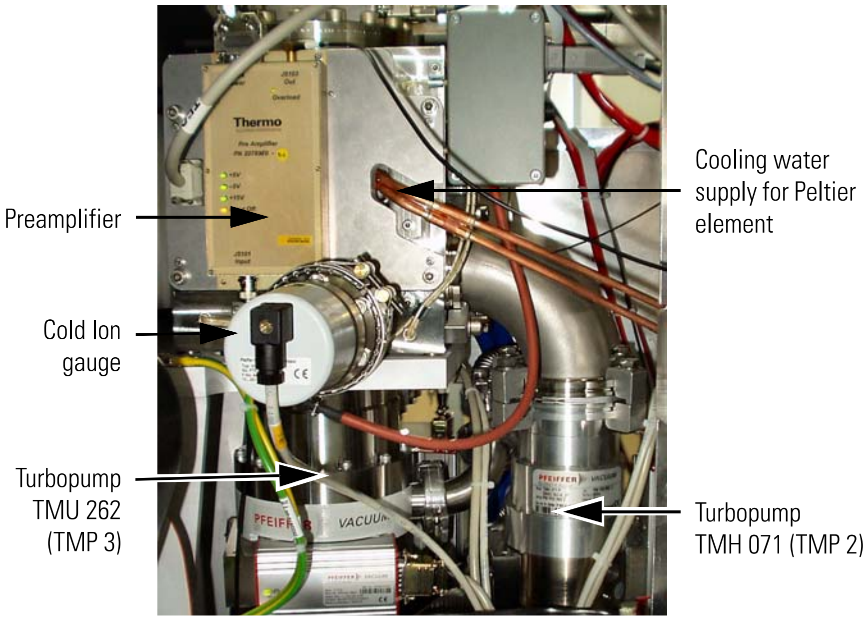


**Figure 1-16.** Vacuum components at the UHV chamber (right instrument side)

The Orbitrap itself is separated from the UHV chamber by differential apertures and is evacuated down to $10^{-10}$ mbar by a 210 L/s turbopump (TMP 3, see Figure 1-16 on page 1-19). All turbopumps are equipped with TC 100 control units (manufacturer: Pfeiffer).

### Linear Trap Turbopump

A separate turbopump provides the high vacuum for the linear ion trap. It it is mounted to the bottom of the vacuum manifold of the linear ion trap. For more information, refer to the *LTQ XL Hardware Manual*.

## Forevacuum Pumps

The rotary vane pumps from the linear trap serve as forepumps for the two smaller turbopumps (TMP 1 and TMP 2). The exhaust hose from the forepumps is led to the back of the instrument and connects them to the exhaust system in the laboratory. The forepumps are located on a small cart in the forepumps cabinet below the linear trap. See Figure 1-17.

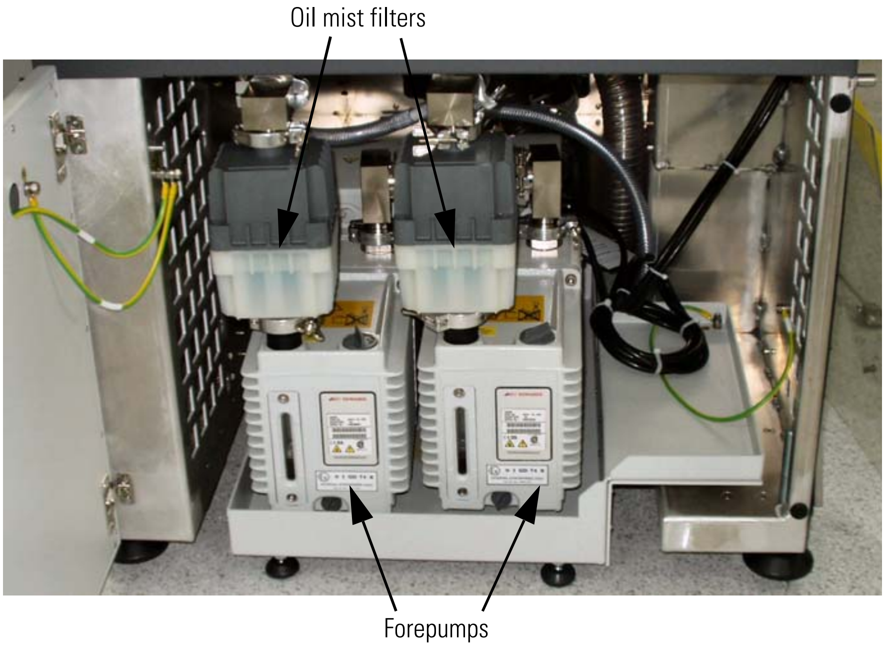


**Figure 1-17.** Forepumps cabinet

To minimize the ingress of pump oil into the exhaust system, the outlets of the forepumps are fitted to oil mist filters. See page 3-6 on instructions about returning the collected oil to the forepumps.

The forevacuum pumps (forepumps) of the linear trap are powered by the power panel of the linear ion trap.

**Warning** When analyzing hazardous materials, these may be present in the effluent of the forepumps! The connection to an adequate exhaust system is mandatory! ▲

Leave the on/off switches of the forepumps always in the On position to provide the control from the vacuum control panel. Before starting the pumps, however, make sure that:

- The forevacuum pumps are filled with oil,
- They are connected to the power supply, and
- The gas ballast is shut.

For a detailed description of the forepumps, refer to the handbook of the manufacturer.

## Vacuum System Controls

The power distribution board controls all turbopumps via voltage levels. Refer to topic "Power Distribution Board" on page 1-36. An interface for RS485 data via the instrument control board connects the turbopumps with the linear ion trap. (Refer to topic "Instrument Control Board" on page 1-34.) The linear ion trap has a separate turbopump controller.

### Vacuum Gauges

The vacuum is monitored by several vacuum gauges:

- The forevacuum of the LTQ Orbitrap MS instrument is monitored by an Active Pirani gauge (TPR 280, manufacturer: Pfeiffer) connected to the LTQ Orbitrap forevacuum line. See photo right and Figure 1-15 on page 1-19.

- The high vacuum of the LTQ Orbitrap MS instrument is monitored by a Cold Ion Gauge (IKR 270, manufacturer: Pfeiffer) connected to the UHV chamber. See Figure 1-16 on page 1-19. Since the gauge would be contaminated at higher pressures, it is only turned on when the forevacuum has fallen below a safety threshold ($<10^{-2}$ mbar).
- The linear ion trap vacuum is monitored by a Convectron gauge and an ion gauge. Refer to the *LTQ XL Hardware Manual* for more information.

The vacuum gauges of the LTQ Orbitrap MS instrument are connected to the power distribution board that directly responds to the pressure values. (Refer to the topic "Power Distribution Board" on page 1-36.)

The analog values are digitized by the instrument control board. (Refer to the topic "Instrument Control Board" on page 1-34.) They are then sent as readout values to the data system.

### Switching on the Vacuum System

When the vacuum system is switched on, the following occurs:

1. After the Vacuum Pumps switch is switched On, the pumps of the linear ion trap and the LTQ Orbitrap MS instrument are run up. The Pirani gauge (see above) controls the LTQ Orbitrap low vacuum pressure as well as the pressure at the forevacuum pumps. Within a short time, a significant pressure decrease must be observed. The goodness of the vacuum can be estimated by means of the rotation speed of the turbopumps (e.g. 80% after 15 min.).

2. If the working pressure is not reached after the preset time, the complete system is switched off. At the status LED panel of the power distribution board, an error message (Vacuum Failure) is put out (see below).

3. The Cold Ion Gauge is only switched on after the low vacuum is reached. It is then used to monitor the vacuum in the Orbitrap region.

### Vacuum Failure

In case the pressure in the LTQ Orbitrap MS instrument or the linear ion trap exceeds a safety threshold, the complete system including linear ion trap, electronics, and pumps is switched off. However, the power distribution is kept under current and puts out an error message at the LED panel. (Refer to the topic "Power Distribution Board" on page 1-36.) It can be reset by switching the main power switch off and on. (Refer to the topic "Main Power Switch" on page 1-10.)

Upon venting, the vent valves of the turbopumps on the Orbitrap detector stay closed. Only the vent valve of the linear ion trap is used. (Refer to the topic "Vent Valve of the Linear Ion Trap" on page 1-24.)

## Vacuum System Heating during a System Bakeout

After the system has been open to the atmosphere (e.g. for maintenance work), the vacuum deteriorates due to contaminations of the inner parts of the vacuum system caused by moisture or a power outage. These contaminations must be removed by heating the vacuum system: a system bakeout. Refer to the topic "Baking Out the System" on page 3-4.

## Gas Supply

Figure 1-18 shows a schematical view of the gas supply in the instrument. The LTQ Orbitrap uses two gases for operation:

- Nitrogen, and
- Helium.

The linear trap requires high-purity (99%) nitrogen for the API sheath gas and auxiliary/sweep gas. The Orbitrap uses nitrogen as collision gas (bath gas) for the curved linear trap. The linear trap requires ultra-high purity (99.999%) helium for the collision gas.

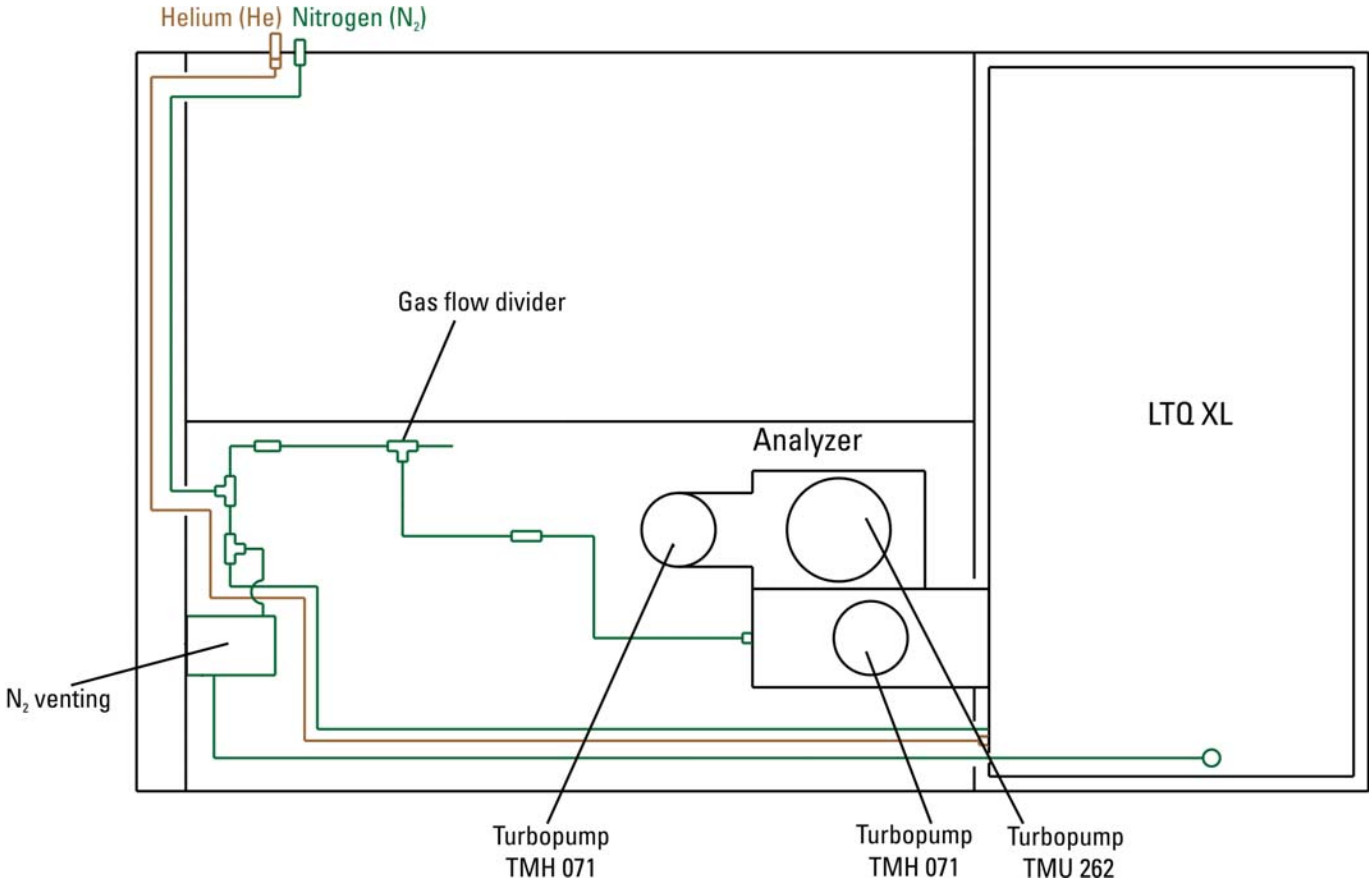


**Figure 1-18.** Schematical view of the gas supply*

*For a parts list of the gas supply, refer to Table 4-5 on page 4-3.

The laboratory gas supply is connected to the inlets at the right side of the instrument. See Figure 1-9 on page 1-11. Within the instrument, the helium gas is led from the helium port through a capillary to the right rear side of the linear trap. Part of the nitrogen gas flow is directed via a pressure regulator to the vent valve of the linear trap. (See below for further information.) Another part of the nitrogen flow is directed to the vacuum chamber of the Orbitrap. Nitrogen gas pressure is kept constant by using an “open-split” interface (gas flow divider, see Figure 1-19). It contains a capillary line from the nitrogen line of the instrument to atmosphere (flow rate: ~5 mL/min), with another capillary leading from the point of atmospheric pressure into the C-Trap (flow rate: ~1.5 mL/min). For the nitrogen gas, PEEKSil™ tubing is used (75 µm ID silica capillary in 1/16 in PEEK tubing).

## Vent Valve of the Linear Ion Trap

If the system and pumps are switched off, the system is vented. The vent valve is controlled by the linear ion trap. The *LTQ XL Hardware Manual* contains further information about the vent valve.

The instrument is vented with nitrogen from the same tubing that supplies the LTQ XL sheath gas. See Figure 1-18 above. The vent valve of the LTQ XL is attached to a pressure regulator that is set to a venting pressure of 3–4 psi. The pressure regulator is located at the left side of the LTQ Orbitrap. See Figure 1-19.

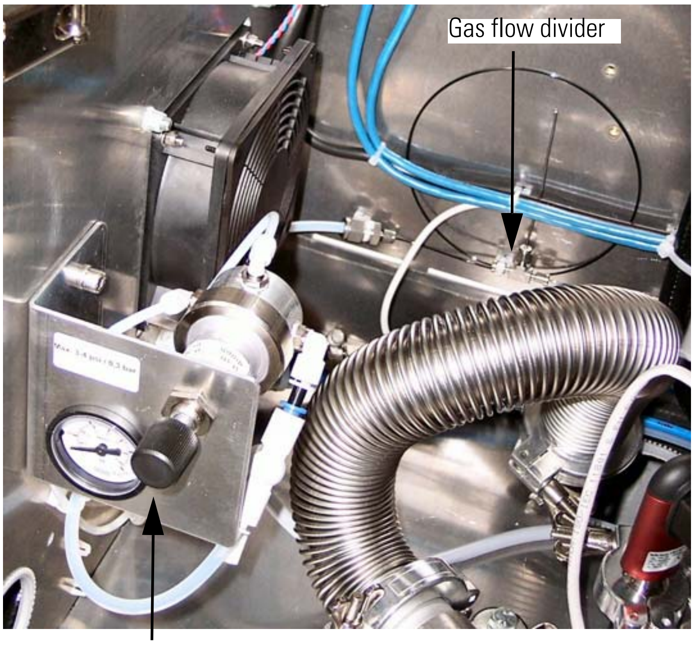


**Figure 1-19.** Nitrogen pressure regulator and gas flow divider

## Cooling Water Circuit

Figure 1-20 on page 1-25 shows a schematical view of the cooling water circuit in the LTQ Orbitrap. Cooling water at a temperature of 20 °C enters and leaves the instrument at the bottom of the right side. See Figure 1-9 on page 1-11. First, the fresh water passes through the turbopumps in the order TMP 3 → TMP 1 → TMP 2. Then it passes through the heating element (Peltier element) that keeps constant (±0.5 °C) the preset temperature of the analyzer. Before it leaves the instrument, the water passes through the other Peltier element at the back of the central electrode power supply board.

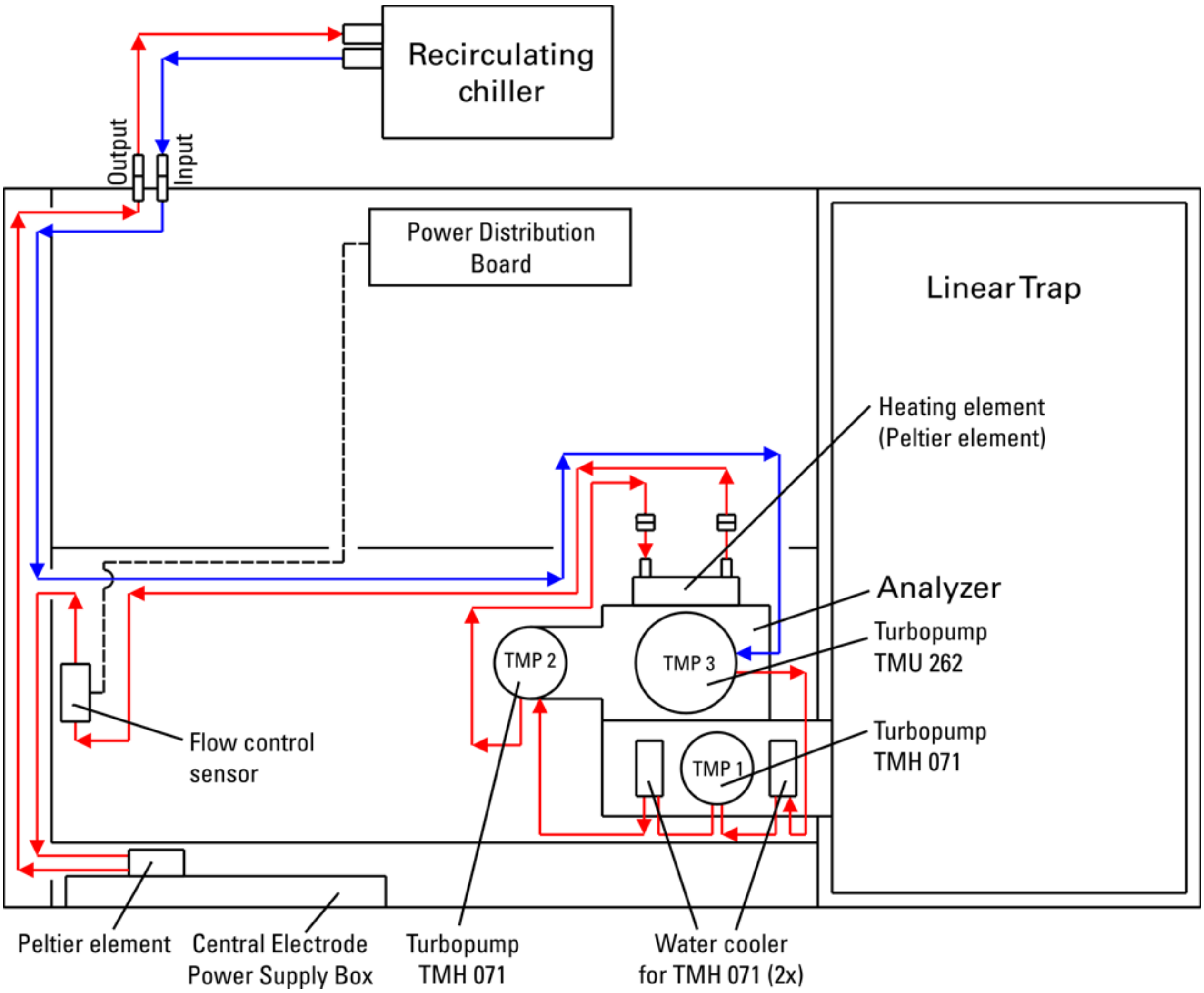


**Figure 1-20.** Schematical view of cooling water circuit*

*For a parts list of the cooling water circuit, refer to Table 4-6 on page 4-3.

A flow control sensor is connected to the power distribution board and allows displaying the current flow rate of the cooling water in the software.

## Recirculating Chiller

A recirculating chiller (Neslab Merlin M 33D PD1)[1] is delivered with the instrument, making the LTQ Orbitrap independent from any cooling water supply. Through the power outlet for peripheral devices, the LTQ Orbitrap provides the electric power for the chiller. See Figure 1-9 on page 1-11. Two water hoses (black), internal diameter 9 mm, wall thickness 3 mm, length approx. 3 m (~10 ft) are delivered with the instrument.

For instruction about performing maintenance for the chiller, see topic “Maintenance of the Recirculating Chiller” on page 3-7. See also the manufacturer’s manual for the chiller.

## Properties of Cooling Water

The water temperature is not critical, but should be in the range of 20 to 25 °C (68 to 77 °F). Lower temperatures could lead to a condensation of atmospheric water vapor. It is recommended to use distilled water rather than de-ionized water due to lower concentration of bacteria and residual organic matter.FF

The water should be free of suspended matter to avoid clogging of the cooling circuit. In special cases, an in-line filter is recommended to guarantee consistent water quality.

The cooling water should meet the following requirements:

| | |
|---|---|
| Hardness: | <0.05 ppm |
| Resistivity: | 1–3 MΩ/cm |
| Total dissolved solids: | <10 ppm |
| pH: | 7–8 |

**Warning Danger of Burns!**
If the water circuit fails, all parts of the water distribution unit may be considerably heated up. Do not touch the parts!
Before disconnecting the cooling water hoses, make sure the cooling water has cooled down! ▲

[1] 50 Hz: P/N 263125030000, 60 Hz: P/N 263116030000

# Printed Circuit Boards

The LTQ Orbitrap MS instrument is controlled by a PC running the Xcalibur software suite. The software controls all aspects of the instrument. The main software elements are the communication with the linear ion trap, the control of ion detection, and the control of the Orbitrap mass analyzer.

The following pages contain a short overview of the various electronic boards of the LTQ Orbitrap. For each board, its respective location and function are given. If applicable, the diagnostic LEDs on the board are described.

The electronics of the LTQ Orbitrap contains complicated and numerous circuits. Therefore, only qualified and skilled electronics engineers should perform servicing.

A Thermo Fisher Scientific Service Engineer should be called if servicing is required. It is further recommended to use Thermo Fisher Scientific spare parts only. When replacing fuses, only use the correct type. Before calling a Service Engineer, please try to localize the defect via errors indicated in the software or diagnostics. A precise description of the defect will ease the repair and reduce the costs.

**Warning** Parts of the printed circuit boards are at high voltage. Opening the electronics cabinet is only allowed for maintenance purposes by qualified personal. ▲

**Note** Many of the electronic components can be tested by the LTQ Orbitrap diagnostics, which is accessible from the Tune Plus window. ▲

## Linear Ion Trap Electronics

The linear ion trap is connected to the LTQ Orbitrap main power switch. The linear ion trap has a sheet metal back cover. Figure 1-21 shows the electronic connections at the rear side of the linear trap.

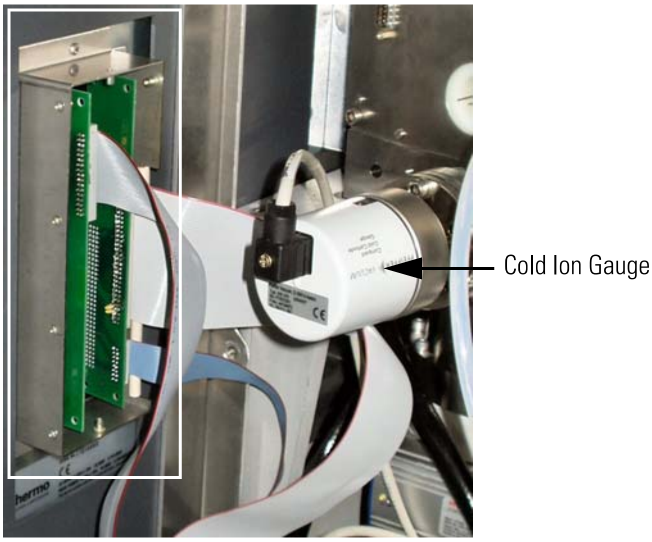


**Figure 1-21.** Electronic connections to linear trap (covers removed)

The linear ion trap electronics has two connections with the LTQ Orbitrap electronics:

- Data communication with the internal computer of the LTQ Orbitrap MS instrument. Refer to the topic "Electronic Boards on the Right Side of the Instrument" on page 1-29.

- Signal communication (SPI bus) with supply information for the instrument control board. Refer to the topic "Instrument Control Board" on page 1-34.

For further information about the linear ion trap electronics, refer to the *LTQ XL Hardware Manual.*

## Electronic Boards on the Right Side of the Instrument

Figure 1-22 shows the parts of the instrument when the right side panel is opened. A transparent cover protects the lower part.

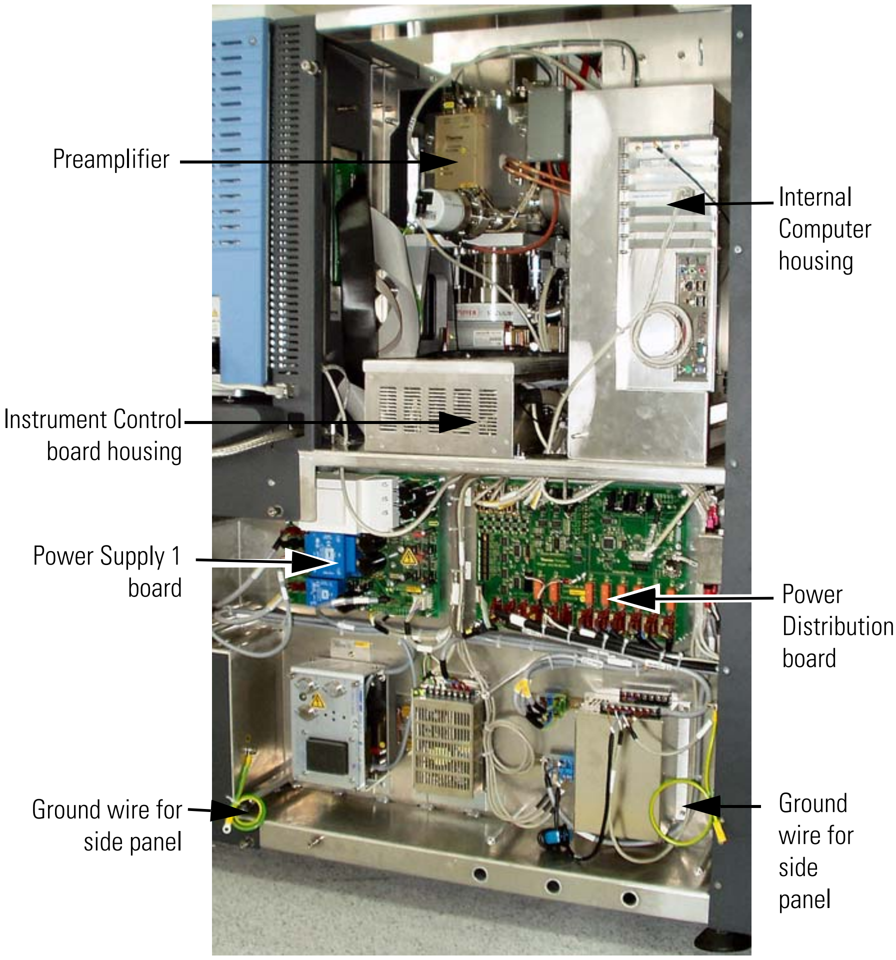


**Figure 1-22.** Electronic boards on the right side of the instrument

The side panel is connected to the instrument frame by two green/yellow ground wires. See bottom of Figure 1-22. The connectors on the panel are labeled with green-yellow PE (for **P**rotective **E**arth) signs. See photo right. Do not forget to reconnect them before closing the panel!

## Preamplifier

Figure 1-23 shows the preamplifier (P/N 207 8900). The preamplifier is located in a housing next to the Cold Ion Gauge.

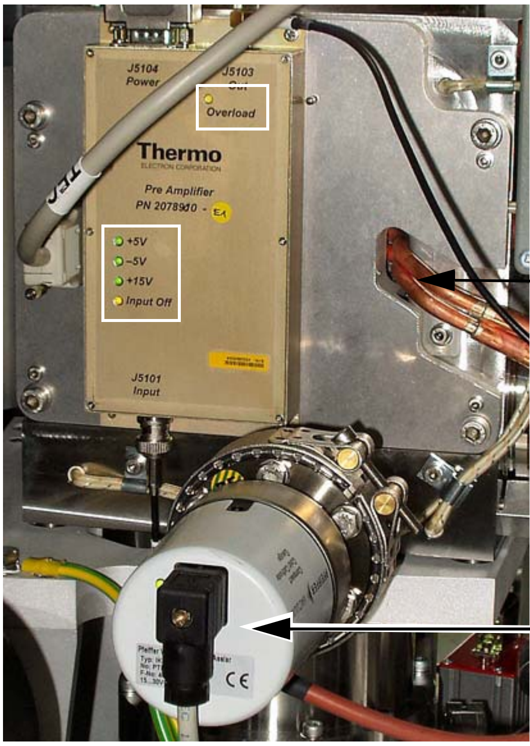


**Figure 1-23.** Preamplifier board

This board is a broadband preamplifier with differential high-impedance inputs. It serves as a detection amplifier and impedance converter for the image current created by the oscillating ions. The output current is transferred to the data acquisition board. It has an amplification factor of about 60 dB and covers the frequency range from 15 kHz to 10 MHz.

The diagnostic LEDs on the preamplifier are listed in Table 1-3. The positions of the diagnostic LEDs on the board are indicated by white rectangles in Figure 1-23 on page 1-30.

**Table 1-3.** Diagnostic LEDs on the Preamplifier board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | Overload | Yellow | RF output is overloaded | Off |
| LD2 | +5 V | Green | +5 V input voltage present | On |
| LD3 | +15 V | Green | +15 V input voltage present | On |
| LD4 | -5 V | Green | -5 V input voltage present | On |
| LD5 | Input off | Yellow | RF inputs are shortened (protection) | On, off during Detect |

## Internal Computer

Figure 1-24 shows the boards of the data acquisition unit (P/N 206 4132). The unit is mounted in a housing located at the right side of the instrument.

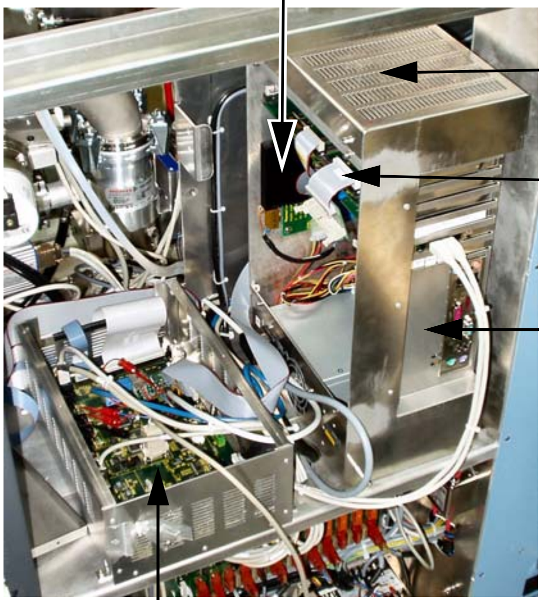


**Figure 1-24.** Data Acquisition unit (covers removed)

The internal computer (P/N 207 6470) contains a computer mainboard with an ATX power supply. The data acquisition digital PCI board is directly plugged into the mainboard. The data acquisition analog board is mounted on top of the mainboard.

## Data Acquisition Digital PCI Board

Figure 1-25 shows the Data Acquisition Digital PCI board (P/N 206 0501). It is an add-on board to the internal computer. (See Figure 1-24 on page 1-31.)

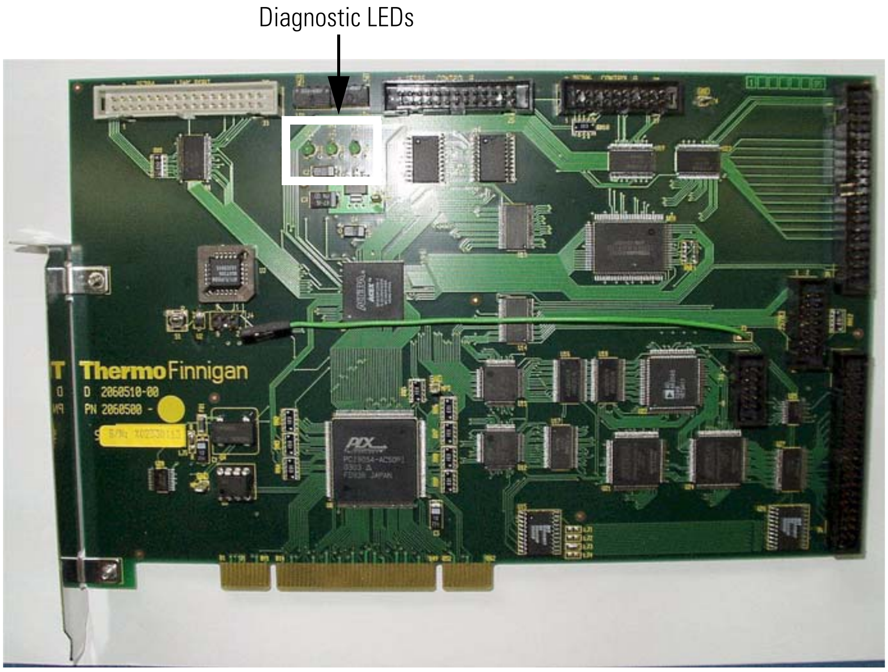


**Figure 1-25.** Data Acquisition Digital PCI board

This board is used to convert detected ion signals to digital form and to interface to the computer mainboard. The board has two 16 bit parallel connections to the DAC and the ADC on the data acquisition analog board, which is used for controlling and reading-back signals. A high-speed link port channel is also on the board that is used to communicate with the electronics in the linear ion trap.

While precision timing is derived from the data acquisition analog board, events with lower requirements use the timer in the internal computer. This timer is used to check at regular intervals whether the foreground process works as expected.

Communication takes place not only between the ion trap and the internal computer of the LTQ Orbitrap system, but also between the ion trap and the data system computer. For further information about the data system, refer to the *LTQ XL Hardware Manual*.

The diagnostic LEDs listed in Table 1-4 on page 1-33 show the status of the board. The position of the LEDs on the board is indicated by a white rectangle in Figure 1-25.

**Table 1-4.** Diagnostic LEDs of the Data Acquisition Digital PCI board

| Name | Color | Description | Normal Operating Condition |
|---|---|---|---|
| +5 V | Green | +5 V voltage present | On |
| +3.3 V | Green | +3.3 V voltage present | On |
| +2.5 V | Green | +2.5 V voltage present | On |

## Data Acquisition Analog Board

Figure 1-26 shows the data acquisition analog board (P/N 206 4150).

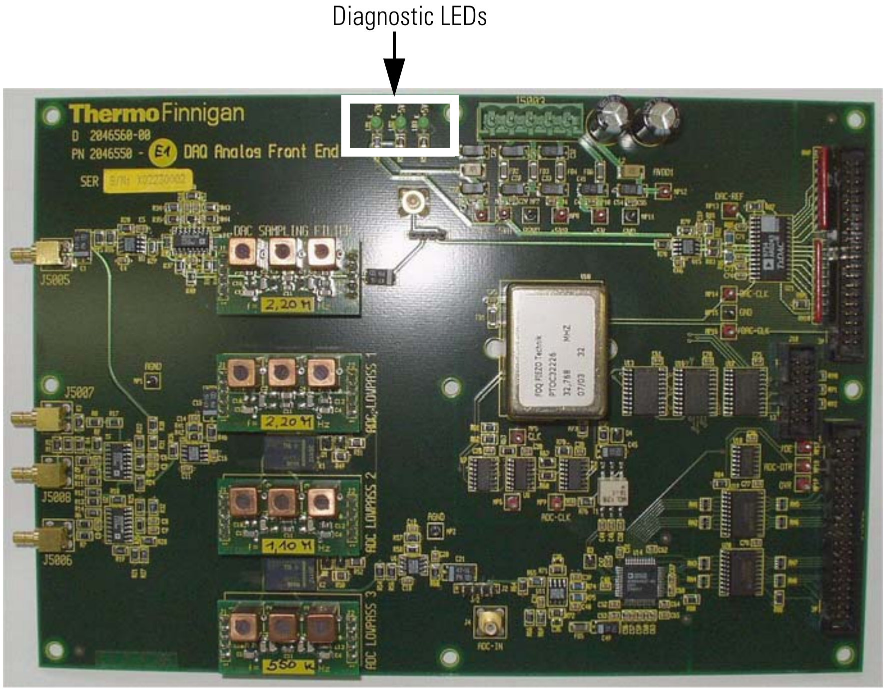


**Figure 1-26.** Data Acquisition Analog board

This board is an add-on board to the mainboard of the internal computer. See Figure 1-24 on page 1-31. It is used to convert analog to digital signals for Orbitrap experiments, especially for detecting the ions. The board contains an ADC for the detection of the transient signal, with a frequency range from 10 kHz to 10 MHz. Three anti-aliasing filters for the low, middle and high mass range are automatically selected by the software.
The data acquisition board provides precision timing to control the acquisition. Events with lower timing requirements on accuracy are controlled by the linear ion trap.

The diagnostic LEDs listed in Table 1-5 on page 1-34 show the status of the voltages applied to the board. The position of the LEDs on the board is indicated by a white rectangle in Figure 1-26.

**Table 1-5.** Diagnostic LEDs of the Data Acquisition Analog board

| Name | Color | Description | Normal Operating Condition |
|---|---|---|---|
| +5 V | Green | +5 V voltage present | On |
| -5 V | Green | -5 V voltage present | On |
| +3.3 V | Green | +3.3 V voltage present | On |

## Power Supply 2 Board

The power supply 2 board (P/N 206 1440) provides the supply voltages for the data acquisition analog board. It is mounted to the back inside the housing of the internal computer. See Figure 1-24 on page 1-31.

The diagnostic LEDs listed in Table 1-6 show the status of the voltages applied to the board.

**Table 1-6.** Diagnostic LEDs of the Power Supply 2 board

| Name | Color | Description | Normal Operating Condition |
|---|---|---|---|
| +5.1 V | Green | +5.1 V voltage present | On |
| -5.1 V | Green | -5.1 V voltage present | On |
| +3.3 V | Green | +3.3 V voltage present | On |

## Instrument Control Board

Figure 1-27 on page 1-35 shows the instrument control board (P/N 205 4221). The instrument control board is located in a housing next to the internal computer.

The instrument control board is used to interface the LTQ XL control electronics to the Orbitrap control electronics. Three signal lines are passed from the LTQ XL: a digital, parallel (DAC) bus, a serial SPI bus, and a Link Port Signal line. The instrument control board contains a micro controller, digital and analog converters, and serial port connectors.

On the instrument control board, analog signals from vacuum gauges are converted to digital signals and passed to the data system as well as to the power distribution board. (See page 1-36.) Turbopumps (Refer to the topic "Vacuum System" on page 1-18.) are attached to a serial port connector and this is connected via the signal lines to the linear ion trap.

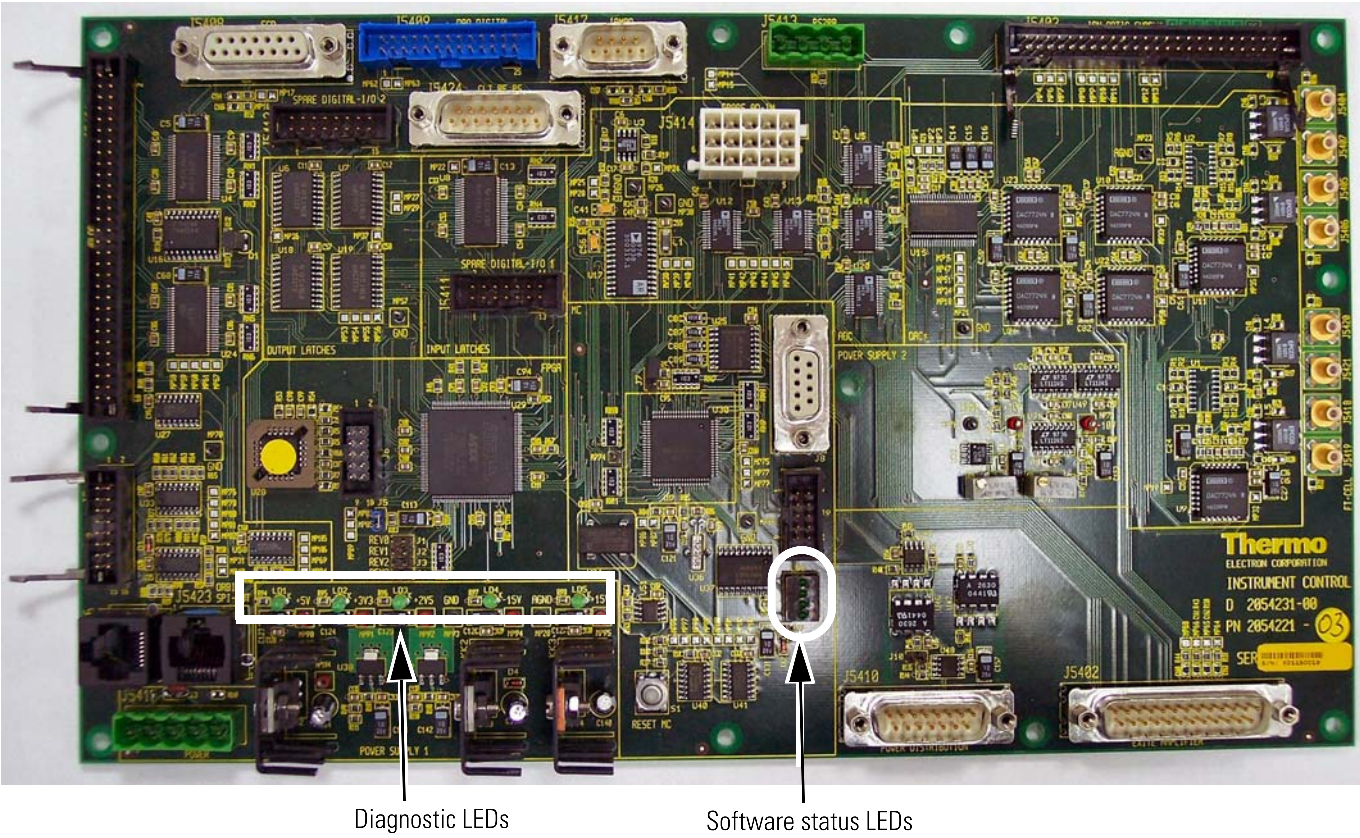


**Figure 1-27.** Instrument Control board

The diagnostic LEDs listed in Table 1-7 show the status of applied voltages to the board. The position of the diagnostic LEDs on the board is indicated by a white rectangle in Figure 1-27.

**Table 1-7.** Diagnostic LEDs of the Instrument Control board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | 2.5 V | Green | 2.55 V Input Voltage present | On |
| LD2 | 3.3 V | Green | 3.3 V Input Voltage present | On |
| LD3 | 5 V | Green | 5 V Input Voltage present | On |
| LD4 | -15 V | Green | -15 V Input Voltage present | On |
| LD5 | +15 V | Green | +15 V Input Voltage present | On |

Additionally, the board contains four green LEDs that are directly connected to the micro controller. They indicate the state of the micro controller and possible error bits and can be used for software debugging. See Table 1-8 on page 1-36. The position of the status LEDs on the board is indicated by a white oval in Figure 1-27.

**Table 1-8.** Software status LEDs of the Instrument Control board

| No. | Description | Normal Operating Condition |
|---|---|---|
| 6.1 | Micro controller is working properly | Permanent flashing of LED |
| 6.2 | CAN bus connection to power distribution board enabled | On |
| 6.3 | Connection to internal computer and LTQ XL SPI bus enabled | On |
| 6.4 | Orbitrap SPI bus enabled | On<br>Flashing on error |

## Power Distribution Board

Figure 1-28 on page 1-37 shows the power distribution board (P/N 206 2130). It is located at the bottom of the right side of the instrument. The power distribution board controls the vacuum system and the system power supplies, including the linear ion trap. Depending on the quality of the vacuum and the status of the turbo molecular pumps, it switches the vacuum gauges, the pumps, and the 230 V relays. It controls external relays with 24 V dc connections. In case of a vacuum failure, it initiates an automatic power down of the instrument.

The power distribution board indicates all system states and error messages by status LEDs (see Table 1-9 on page 1-38) in the middle of the left side of the board. A green LED indicates that the status is OK. An orange LED indicates a status that differs from normal. The position of the LEDs on the board is indicated by a white oval in Figure 1-28 on page 1-37.

The system status LEDs on the front side of the instrument are controlled by the power distribution board. The information partially comes from external boards, e.g. the Comm. LED is controlled by the instrument control board. (Refer to topic "Instrument Control Board" on page 1-34.)

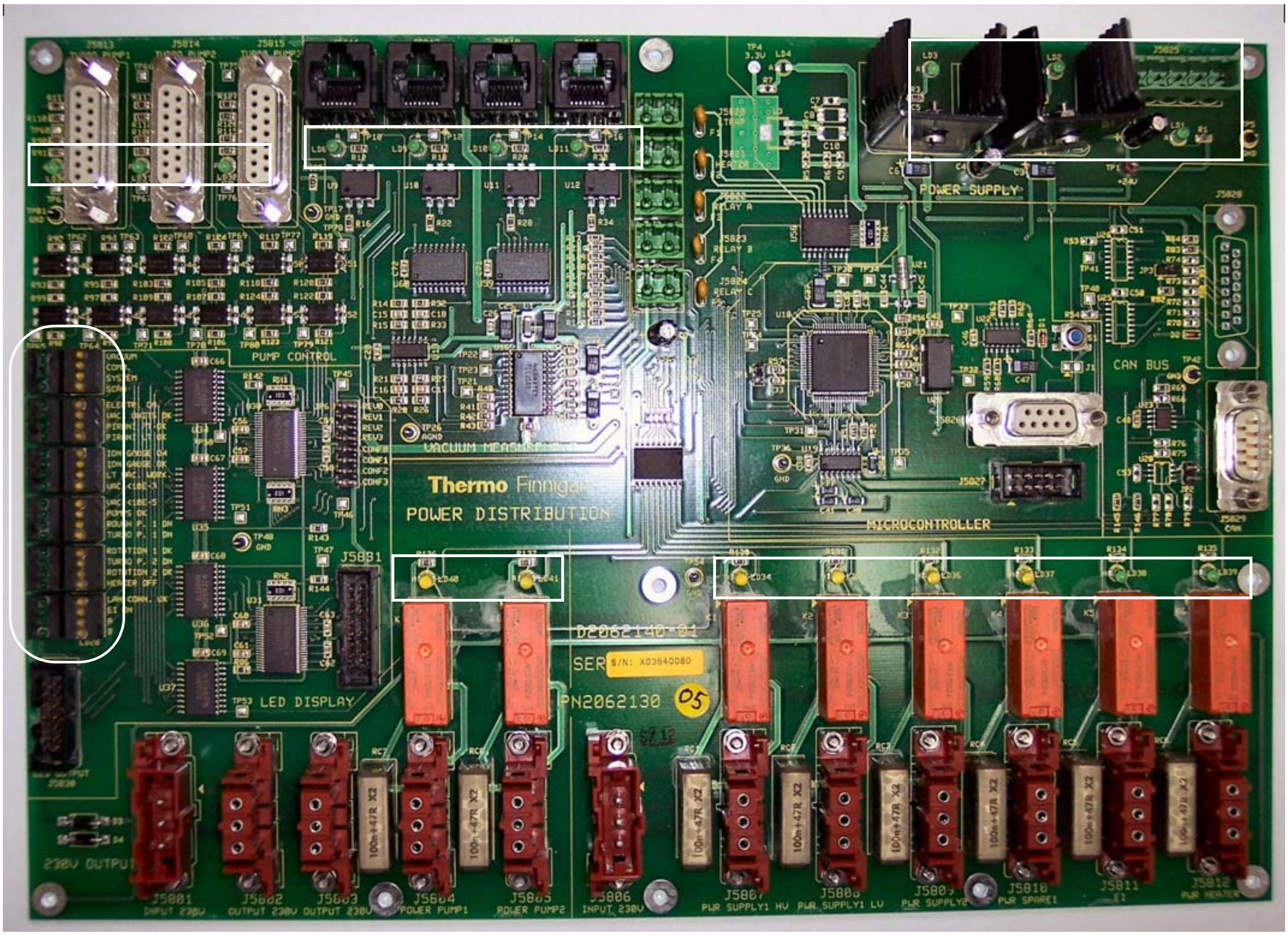


**Figure 1-28.** Power Distribution board

Diagnostic LEDs show the status of voltages applied from the board to other devices. The positions of the diagnostic LEDs on the board are indicated by white rectangles in Figure 1-28.

**Table 1-9.** Status LEDs of the Power Distribution board

| LED green | LED orange | Information given by orange LED |
|---|---|---|
| Vacuum | High vacuum failure | High vacuum pressure > $10^{-8}$ mbar |
| Comm. | No communication with instrument control board | CAN bus problem or instrument control board not working |
| System | System is not ready | FT Electronics switch off or Vacuum Pumps switch off |
| Scan | | Instrument is not scanning |
| Electr. On | Service mode | FT Electronics switch in OFF position |
| Vac. Units Ok | Vacuum measurement failure | Vacuum gauge defective |
| Pirani Orbitrap Ok | No function, at present | |
| Pirani LT Ok | Pirani LTQ XL failure | Control signal < 0.5 V |
| Ion Gauge ON | Penning (Cold Ion Gauge) LTQ Orbitrap off | Forevacuum > $10^{-2}$ mbar |
| Ion Gauge OK | Penning LTQ Orbitrap failure | Control signal < 0.5 V |
| LT Vacuum Work | LTQ XL vacuum failure | Vacuum forepump LTQ XL >$10^{-1}$ mbar |
| Vac. <$10^{-3}$ | Forevacuum failure | Forevacuum > $10^{-3}$ mbar |
| Vac. <$10^{-5}$ | High vacuum failure | High vacuum > $10^{-5}$ mbar |
| Pumps OK | Pumps Off | Pump down; leakage |
| Rough P. 1 ON | Forepump #1 failure | Forepump defective |
| Turbo P. 1 ON | Turbopump #1 failure | Turbopump defective/error* |
| Rotation 1 OK | Turbopump #1 failure | 80% rotation speed of turbopump not reached |
| Turbo P. 2 ON | Turbopump #2 failure | Turbopump defective/error* |
| Rotation 2 OK | Turbopump #2 failure | 80% rotation speed of turbopump not reached |
| Heater Off | Heater enabled | Heater enabled |
| LAN Conn. Ok | LAN connection failure | LAN interrupted (Option) |
| EI ON | No function, at present | |
| A | System reset | System reset has occured |
| B | | Micro controller idle |

*An error of turbopump 3 is indicated by an LED directly located on the pump controller.

Depending on user actions, the power distribution is switched to various working modes by the hardware. See Table 1-10.

**Table 1-10.** Working modes of the Power Distribution board

| | Action | Consequences |
|---|---|---|
| a. | Main switch off | Complete system including linear ion trap and multiple socket outlets (recirculating chiller and data system) are without power |
| b. | Vacuum Pumps switch off | Everything is switched off |
| c. | FT Electronics switch off | All components are switched off with exception of the following ones:<br>• Heater control<br>• Multiple socket outlets<br>• Power distribution board<br>• Pumps<br>• Vacuum control<br>• LTQ XL (has a separate Service switch) |

Table 1-11 shows the possible operating states of the power distribution.

**Table 1-11.** Operating states of the Power Distribution board

| | Action | Consequences |
|---|---|---|
| 1. | Main switch on, Vacuum Pumps switch off | Everything is switched off |
| 2. | Vacuum Pumps switch on and FT Electronics switch on | System starts up: pumps and electronics switched on |
| 3. | Check linear ion trap and LTQ Orbitrap forevacuum pump:<br>$10^{-0}$ mbar after 30 s. | If not ok: switch off system and light error LED*; power distribution remains switched on |
| 4. | After the system has started, the Pirani gauge returns a vacuum < $10^{-2}$ mbar and both turbopumps reach 80% rotation speed | Switch on Penning gauge (Cold Ion Gauge |
| 5. | Vacuum and 80% rotation speed of turbopumps not reached after preset time (< 8 min., otherwise the pumps are automatically switched off) | Switch off system (including linear ion trap) and light error LED*; power distribution remains switched on |
| 6. | One or more vacuum gauges defective (control signal < 0.5 V) | Light error LED only, otherwise ignore |

**Table 1-11.** Operating states of the Power Distribution board, continued

| | Action | Consequences |
|---|---|---|
| 7. | After the operating status is reached, the pressure at one gauge exceeds the security threshold for more than the preset time period:<br>• Pirani gauge LTQ Orbitrap > $10^{-1}$ mbar<br>• Penning gauge LTQ Orbitrap > $10^{-3}$ mbar<br>• Pirani gauge LT forepump >$10^{-1}$ mbar | System is shut down with exception of power distribution (light error LED).<br><br>Rebooting of the system by switching off/on of the main switch. |
| 8. | Rotation speed of a turbopump falls below 80% | Shut down system (see 7.);<br>light LED* of corresponding pump. |
| 9. | Service switch linear ion trap off | Linear ion trap electronics switched off, pumps keep on running;<br>LTQ Orbitrap without data link, keeps on running |
| 10. | FT Electronics switch LTQ Orbitrap off | LTQ Orbitrap electronics switched off, pumps keep on running;<br>LTQ Orbitrap without data link, keeps on running |
| 11. | Failure of linear ion trap or LTQ Orbitrap (e.g. fuse is opened). | If the vacuum in one part deteriorates, the complete system is shut down. |
| 12. | Mains failure | System powers up after the electricity is available again. All devices reach the defined state. Linear ion trap and internal computer must reboot. |

* After the shutdown, the LED flashes that represents the reason for the shutdown.

## Power Supply 1 Board

Figure 1-29 on page 1-41 shows the power supply 1 board (P/N 205 5810). This board is located next to the power distribution board. It provides the power for the ion optic supply board (Refer to topic "Ion Optic Supply Board" on page 1-42.) and the instrument control board. (Refer to topic "Instrument Control Board" on page 1-34.)

**Figure 1-29.** Power Supply 1 board

The diagnostic LEDs listed in Table 1-12 show the status of the voltages applied to the board. The position of the LEDs on the board is indicated by the white rectangles in Figure 1-29.

**Table 1-12.** Diagnostic LEDs of the Power Supply 1 board

| Name | Color | Description | Normal Operating Condition |
|---|---|---|---|
| +285 V | Green | +285 V Output voltage present | On |
| -285 V | Green | -285 V Output voltage present | On |
| Over Current +285 V | Red | LED lit dark red: $I_{out}$ > 80 mA<br>LED lit bright red: output is short-circuited | Off |
| Over Current -285 V | Red | LED lit dark red: $I_{out}$ > 80 mA<br>LED lit bright red: output is short-circuited | Off |
| +18 V | Green | +18 V Output voltage present | On |
| -18 V | Green | -18 V Output voltage present | On |
| +8.5 V | Green | +8.5 V Output voltage present | On |

**Warning** Parts of the power supply 1 board are at high voltage. ▲

## Electronic Boards on the Left Side of the Instrument

Figure 1-30 shows the left side of the instrument with the panel opened.

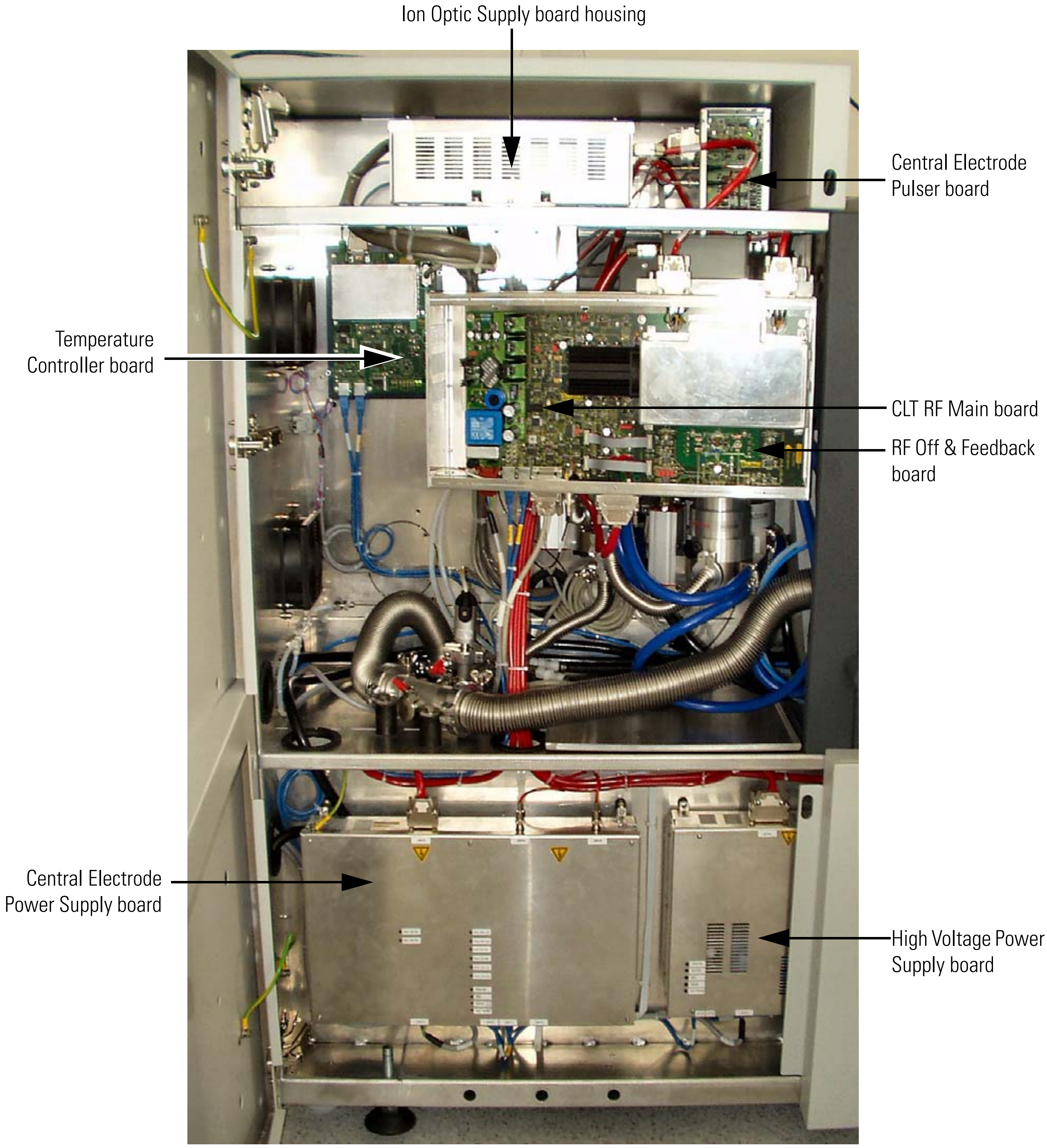


**Figure 1-30.** Electronic boards on the left side of the instrument

The main components on this side are described starting from the top.

### Ion Optic Supply Board

Figure 1-31 shows the ion optic supply board (P/N 208 5070). The board is located in a housing on top of the left side of the instrument. This board supplies the voltage and the radio frequency for the ion guides and interoctapole lenses of the LTQ Orbitrap. It has an

RF detector for the RF output control. The board also provides the trap voltage, gate voltage, and reflector dc voltages as well as the RF voltages to the octapole 1 of the Orbitrap. See topic "Orbitrap Analyzer" on page 1-13 for further information.

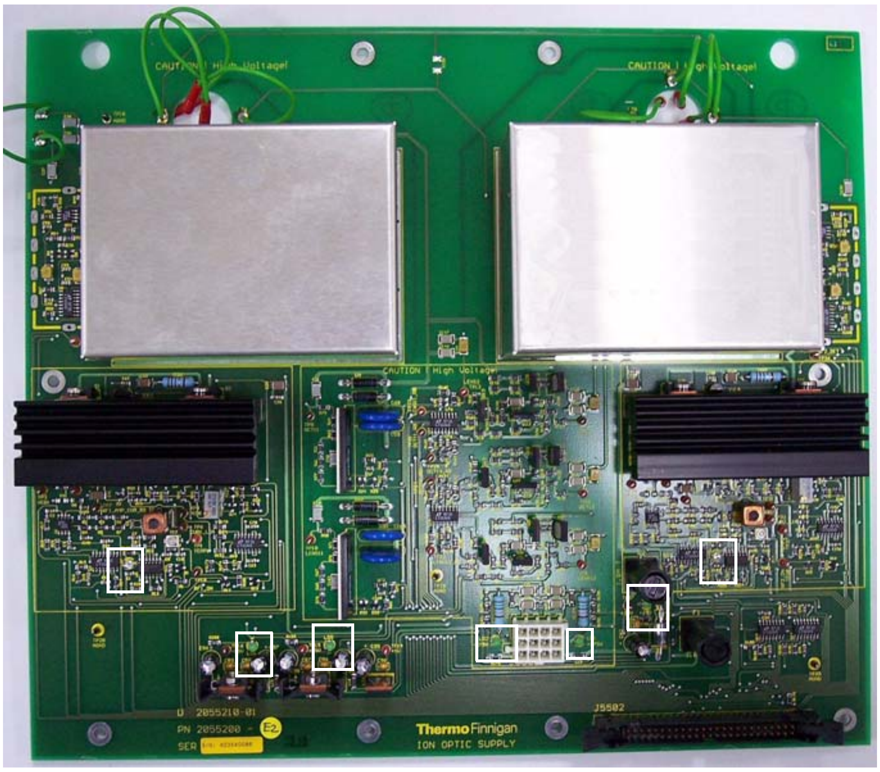


**Figure 1-31.** Ion Optic Supply board

The diagnostic LEDs listed in Table 1-13 on page 1-44 show the status of applied voltages to the board. The position of the LEDs on the board is indicated by white rectangles in Figure 1-31.

**Warning** Parts of the board are at high voltage. ▲

**Table 1-13.** Diagnostic LEDs of the ion optic supply board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | +275 V | Green | +275 V Input voltage present | On |
| LD2 | -275 V | Green | -275 V Input voltage present | On |
| LD3 | +29 V | Green | +29 V Input voltage present | On |
| LD5 | +15 V | Green | +15 V Input voltage present | On |
| LD6 | -15 V | Green | -15 V Input voltage present | On |
| LD7 | RF1_ON | Blue | RF1 generator switched on | depending on application; LED flashes during scanning |
| LD8 | RF2_ON | Blue | RF2 generator switched on | depending on application; LED flashes during scanning |

## Central Electrode Pulser Board

The central electrode pulser board (P/N 207 9640) is located in a housing that is mounted to the flange of the UHV chamber.

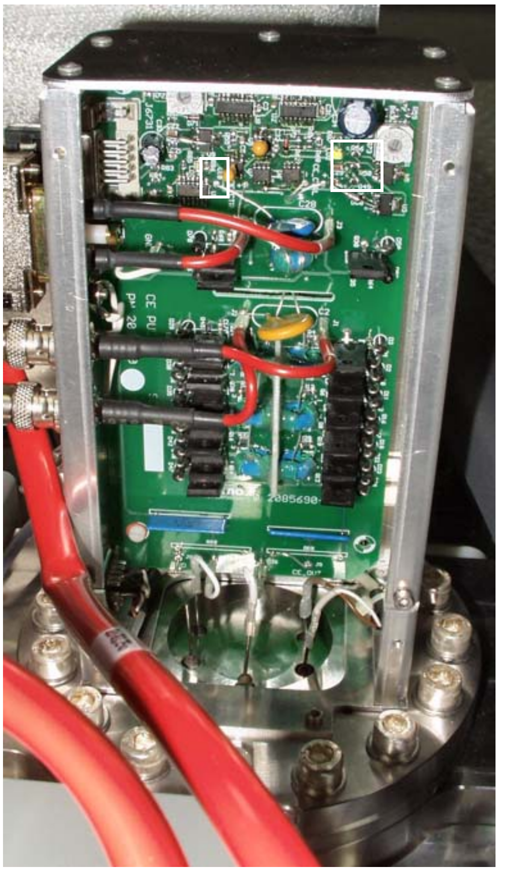

**Figure 1-32.** Central Electrode Pulser board

The board switches the injection and measurement voltages for the central electrode and the detection electrodes of the Orbitrap. Resistor-capacitor circuits on the board convert the switching pulse into a smooth transition between the voltages.

The diagnostic LEDs listed in Table 1-14 show the status of the voltages applied to the board as well as some operating states. The position of the LEDs on the board is indicated by the white rectangles in Figure 1-32 on page 1-44.

**Table 1-14.** Diagnostic LEDs of the Central Electrode Pulser board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | TRIG | Green | Trigger signal indicator | Flashing when scanning |
| LD2 | PS | Green | 24V Power Supply is OK | On |

## Temperature Controller Board

The temperature controller board (P/N 207 8930) is located on the top left side of the instrument, next to the CLT RF main board. See Figure 1-30 on page 1-42. The temperature controller board keeps the temperature of the analyzer chamber to a preset value. A Peltier element that can be used for heating as well as for cooling is used as an actuator. Activation is done via the serial SPI (Serial Peripheral Interface) bus.

**Figure 1-33.** Temperature Controller board

The diagnostic LEDs listed in Table 1-15 show the status of the voltages applied to the board as well as some operating states. The positions of the LEDs on the board are indicated by the white rectangles in Figure 1-33.

**Table 1-15.** Diagnostic LEDs of the Temperature Controller board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | +15 V | Green | +15 V Input voltage present | On |
| LD2 | -15 V | Green | -15 V Input voltage present | On |
| LD3 | TEC >60C | Yellow | Temperature of cold side Peltier element above 60 °C | Off |
| LD4 | Unit >60C | Yellow | Temperature of UNIT heat sink above 60 °C | Off |
| LD5 | Reg Off | Yellow | Control switched off | Off |
| LD6 | No Term. | Yellow | SPI bus termination board missing | Off |
| LD7 | SDT enable | Green | Interface has been addressed and sends/receives data | Flashing on SPI bus data transfer |
| LD8 | SEL | Green | Board has been addressed | Flashing on SPI bus data transfer |
| LD9 | Heating | Yellow | Peltier element is heating | Depending on system state |
| LD10 | Cooling | Yellow | Peltier element is cooling | Depending on system state |
| LD11 | UR>0 | Yellow | Summation voltage controller >0 V | Off when adjusted |
| LD12 | UR<0 | Yellow | Summation voltage controller <0 V | Off when adjusted |

## CLT RF Unit

The CLT RF main board and RF off & feedback board comprise the CLT RF unit (P/N 207 9580). The unit operates the curved linear trap (C-Trap) with four phases RF voltage and three pulsed dc voltages (PUSH, PULL and OFFSET).

The CLT RF main board (P/N 207 9590) is located in a housing in the center of the left side of the instrument. See Figure 1-30 on page 1-42. This board provides an RF voltage (“Main RF”) for the C-Trap. It allows switching off the RF and simultaneous pulsing of each C-Trap electrode. See topic “Orbitrap Analyzer” on page 1-13 for further information. The board communicates with the instrument control board via an SPI bus.

The RF off & feedback board (P/N 208 2540) is an add-on board to the CLT RF main board. It is located in the same housing. See Figure 1-34 on page 1-47.

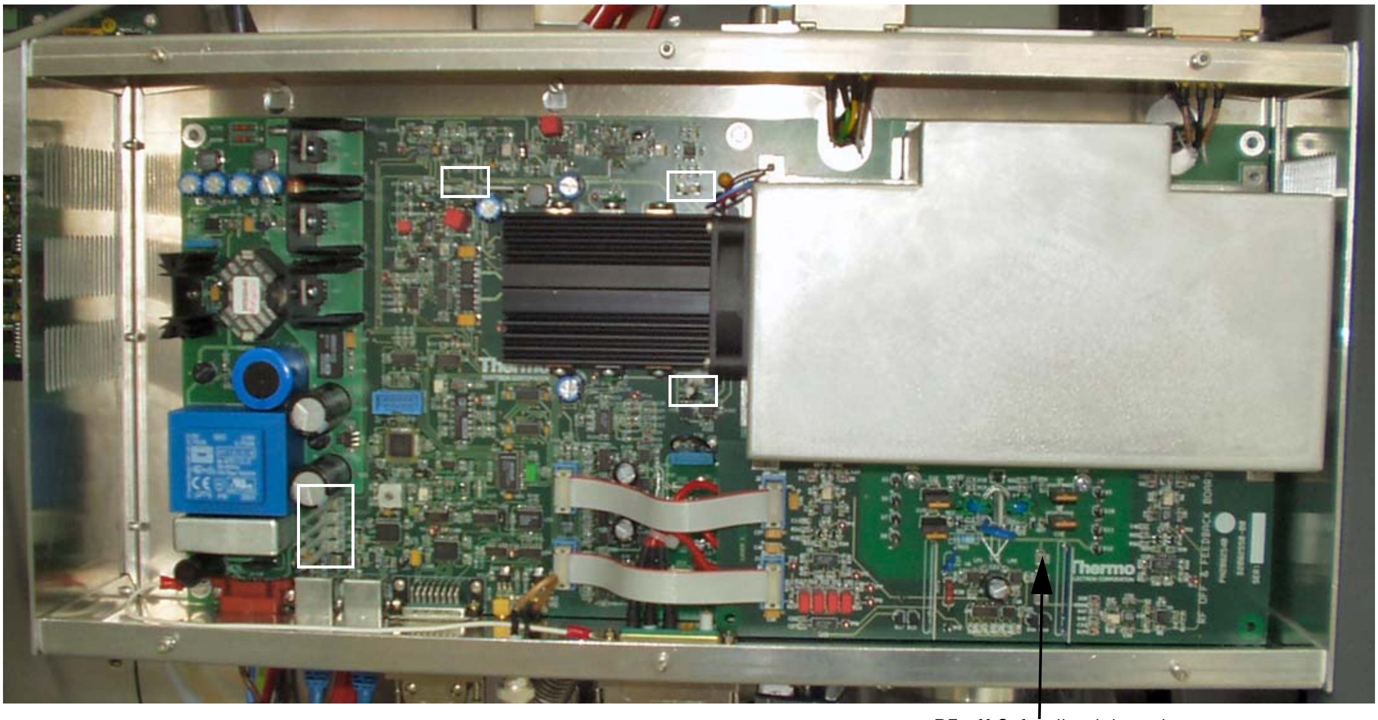


**Figure 1-34.** CLT RF unit (cover removed)

The diagnostic LEDs listed in Table 1-16 show the status of the voltages applied to the board as well as some operating states. The position of the LEDs on the board is indicated by the white rectangles in Figure 1-34.

**Table 1-16.** Diagnostic LEDs of the CLT RF Main board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | NO TERM | Yellow | SPI bus termination board missing | Off |
| LD2 | SEND | Yellow | Interface has been addressed and sends/receives data | Flashing on SPI-bus data transfer |
| LD3 | SEL | Green | Board has been addressed | Flashing on SPI-bus data transfer |
| LD4 | POLAR | Blue | Negative Ions operating mode. (Not used anymore) | Off |
| LD5 | NO LOCK | Yellow | PLL has been not locked | Off |
| LD6 | OVL | Yellow | RF Amplifier overload | Off |
| LD7 | OVHEAT | Red | Heatsink temperature > 73 °C | Off |

## Central Electrode Power Supply Board

The central electrode power supply board (P/N 207 9610) is mounted in a housing on the bottom left side of the instrument.

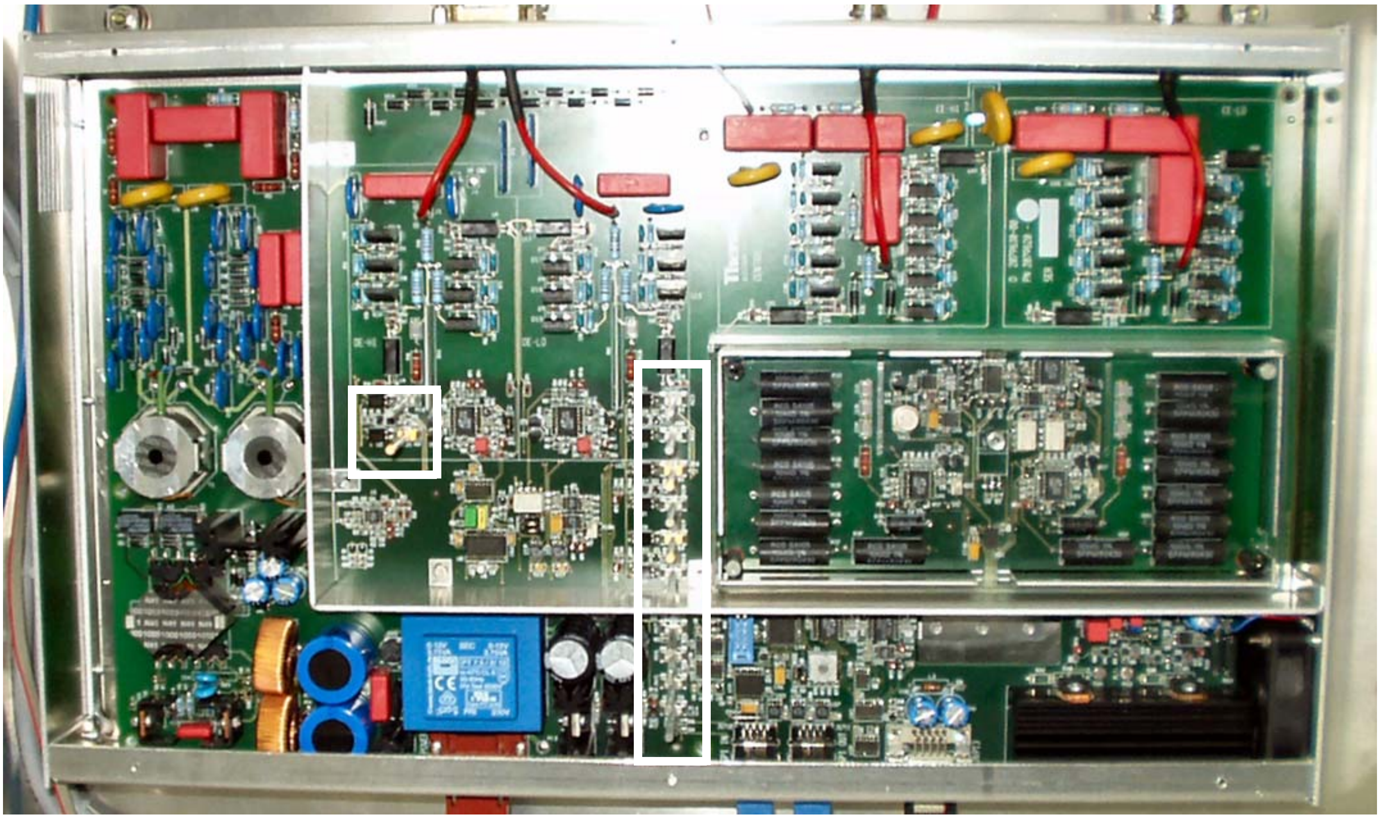

**Figure 1-35.** Central Electrode Power Supply board (cover removed)

The board supplies four dc voltages to the Orbitrap:

- Two central electrode (CE) voltages: CE HIGH and CE LOW
- Two deflector electrode (DE) voltages: DE HIGH and DE LOW.

For positive ions, the CE voltages are negative and the DE voltages are positive. The maximum CE voltage is 3 kV and the maximum DE voltage is 1 kV. The board communicates via the SPI bus.

In addition to a ventilator on the bottom right side, a water-cooled Peltier element on the rear side of the board serves as means of heat dissipation.

The diagnostic LEDs listed in Table 1-17 on page 1-49 show the status of the voltages applied to the board as well as some operating states. The position of the LEDs on the board is indicated by the white rectangles in Figure 1-35.

**Table 1-17.** Diagnostic LEDs of the Central Electrode Power Supply board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | OVL DE HI- | Yellow | Negative side of Deflector High Supply has been overloaded | Off |
| LD2 | OVL DE HI+ | Yellow | Positive side of Deflector High Supply has been overloaded | Off |
| LD3 | No Term | Yellow | SPI bus termination missing | Off |
| LD4 | Send | Yellow | Interface has been addressed and sends/receives data | Flashing on SPI-bus data transfer |
| LD5 | Sel | Green | Board has been addressed | Flashing on SPI-bus data transfer |
| LD6 | Polarity | Blue | Positive/negative ion mode | Off (positive mode) |
| LD7 | OVL CE LO+ | Yellow | Positive side of Central Electrode Low Supply has been overloaded | Off |
| LD8 | OVL CE LO- | Yellow | Negative side of Central Electrode Low Supply has been overloaded | Off |
| LD9 | OVL CE HI+ | Yellow | Positive side of Central Electrode High Supply has been overloaded. | Off |
| LD10 | OVL CE HI- | Yellow | Negative side of Central Electrode High Supply has been overloaded | Off |
| LD11 | OVL DE LO+ | Yellow | Positive side of Deflector Low Supply has been overloaded. | Off |
| LD12 | OVL DE LO- | Yellow | Negative side of Deflector Low Supply has been overloaded. | Off |

## High Voltage Power Supply Board

The high voltage power supply board (P/N 207 7990) is mounted in a housing on the bottom left side of the instrument. See Figure 1-30 on page 1-42. This board provides nine dc voltages for the ion optics of the LTQ Orbitrap. Five voltages supply the lenses of the instrument. Four voltages are applied to the RF CLT main board to be used as focusing potentials for the curved linear trap. See topic "Orbitrap Analyzer" on page 1-13 for further information. The board communicates via the SPI bus.

**Warning** The high voltage power supply board creates voltages up to 3.5 kV! ▲

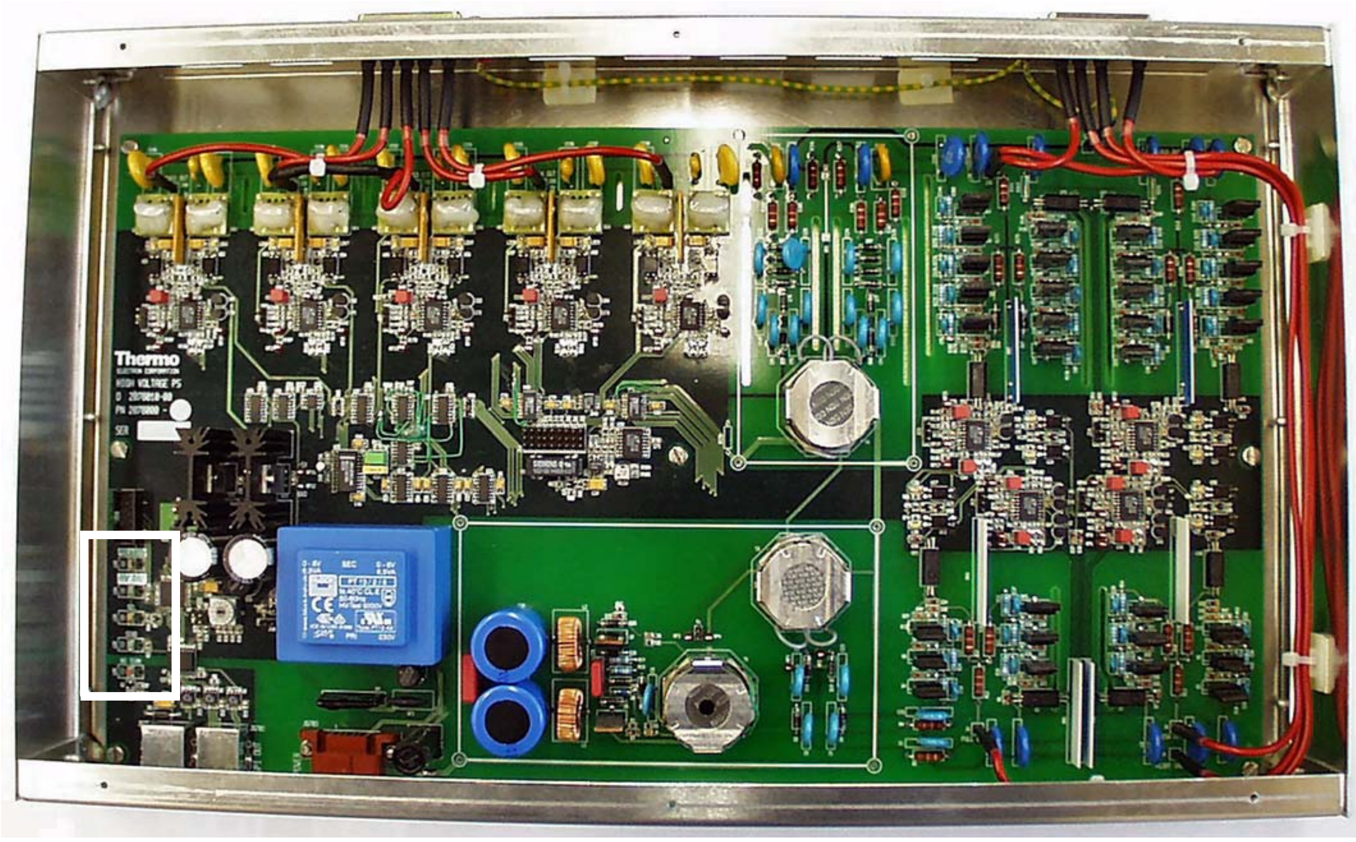

**Figure 1-36.** High Voltage Power Supply board (cover removed)

The diagnostic LEDs listed in Table 1-18 show the operating states of the board. The position of the LEDs on the board is indicated by the white rectangles in Figure 1-36.

**Table 1-18.** Diagnostic LEDs of the High Voltage Power Supply board

| No. | Name | Color | Description | Normal Operating Condition |
|---|---|---|---|---|
| LD1 | NO TERM | Yellow | SPI bus termination board missing | Off |
| LD2 | SEND | Yellow | Interface has been addressed and sends/receives data | Flashing on SPI-bus data transfer |
| LD3 | SEL | Green | Board has been addressed | Flashing on SPI-bus data transfer |
| LD4 | HV ON | Green | High voltage is switched on | On |
| LD5 | POLARITY | Green | Positive/negative ion mode | Off (positive mode) |

## SPI Bus Termination Board

Various boards communicate via the SPI bus, a serial RS485-based bus system. The SPI bus termination board reduces unwanted signal reflections. The boards indicate a missing termination (after maintenance, for example) by LEDs.

The SPI bus termination board (P/N 208 1480) is located at the bottom left side of the instrument, below the high voltage power supply board. See Figure 1-37.


**Figure 1-37.** High voltage power supply board with SPI Bus Termination board

# Chapter 2 Basic System Operations

Many maintenance procedures for the LTQ Orbitrap system require that the MS detector be shut down. In addition, the LTQ Orbitrap system can be placed in Standby condition if the system is not to be used for 12 h or more.

The following topics are discussed in this chapter:

## Shutting Down the System in an Emergency

To **turn** off the instrument in an emergency, place the main power switch (located on the power panel at the right side of the LTQ Orbitrap) in the Off (O) position. This turns off all power to the instrument, including the linear ion trap, multiple socket outlets for the recirculating chiller and data system, and the vacuum pumps. The main power switch must be turned 90° anti-clockwise to switch off the instrument. See Figure 2-1.

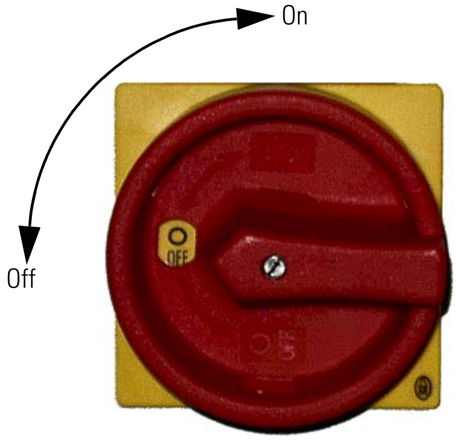


**Figure 2-1.** Main power switch in Off position

The instrument is automatically vented by the vent valve of the linear ion trap. The vent valve vents the system 30 s after power is switched off.

Although removing power abruptly will not harm any component within the system, this is not the recommended shutdown procedure to follow. Refer to topic "Shutting Down the System" on page 2-5 for the recommended procedure.

**Note** To separately turn off the recirculating chiller or computer in an emergency, use the On/Off switches on the chiller and computer, respectively. ▲

## Behavior of the System in Case of a Main Failure

A main power failure has the same consequence as switching off via the main power switch. When the power is available again, the system is started up automatically: the pumps are switched on and the vacuum is created. If the system has been vented during the mains failure, it is necessary to bakeout the system to obtain the operating vacuum. Refer to the topic "Baking Out the System" on page 3-4.

It is not possible to check whether the system was vented. The log file of the data system indicates a reboot of the system. In case of frequent but short power failures we recommend installing an uninterruptible power supply (UPS). If main power failures occur frequently while the system is not attended (e.g. in the night), we recommend installing a power fail detector.

**Note** The intentional venting of the system is performed with the vent valve of the linear ion trap. ▲

## Placing the System in Standby Condition

The LTQ Orbitrap system should not be shut down completely if you are not going to use it for a short period of time, such as overnight or over the weekend. When you are not going to operate the system for 12 hours or more, you can leave the system in Standby condition.

Use the following procedure to place the LTQ Orbitrap system in the Standby condition:

1. Wait until data acquisition, if any, is complete.

2. Turn off the flow of sample solution from the LC (or other sample introduction device).

**Note** For instructions on how to operate the LC from the front panel, refer to the manual that came with the LC. ▲

3. From the Tune Plus window, choose Control > **Standby** (or click on the **On/Standby** button to toggle it to Standby) to put the instrument in Standby condition. The consequences of this user action are described in the *LTQ XL Hardware Manual*. The System LED on the front panel of the LTQ XL is illuminated yellow when the system is in Standby condition.

4. Leave the LC power On.

5. Leave the autosampler power On.

6. Leave the data system power On.

7. Leave the LTQ Orbitrap main power switch in the On position.

## Shutting Down the System

The LTQ Orbitrap system does not need to be shut down completely if you are not going to use it for a short period of time, such as overnight or over a weekend. Refer to the topic "Placing the System in Standby Condition" on page 2-4. This section describes how to shut down the system for a maintenance or service procedure.

Use the following procedure to shut down the LTQ Orbitrap system:

1. Wait until data acquisition, if any, is complete.

2. Turn off the flow of sample solution from the LC (or other sample introduction device).

**Note** For instructions on how to operate the LC from the front panel, refer to the manual that came with the LC. ▲

3. From the Tune Plus window, choose Control > **Off** to put the instrument in Off condition. When you choose Control > **Off**, all high voltages are shut off, as are the sheath and auxiliary gas.

4. Put the FT Electronics switch to the OFF position. See Figure 1-7 on page 1-9.

5. Put the Vacuum Pumps switch to the OFF position. See Figure 1-7. When you place the switch in the OFF position, the following occurs:

    a. All power to the instrument, including the turbomolecular pumps and the rotary-vane pumps, is turned off.

    b. After 30 s, power to the vent valve solenoid of the ion trap is shut off. The vent valve opens and the vacuum manifold is vented with nitrogen to atmosphere pressure through a filter. You can hear a hissing sound as the gas passes through the filter.

6. Leave the main power switch of the LTQ Orbitrap in the On position.

7. During service or maintenance operations that require opening the vacuum system of the LTQ XL or LTQ Orbitrap, always put the main switch (main circuit breaker) to the OFF position. You can secure the main switch with a padlock or tie-wrap to prevent unintended re-powering.

**Warning** Allow heated components to cool before you service them (the ion transfer tube at about 300 °C, for example). ▲

**Note** If you are planning to perform routine or preventive system maintenance on the LTQ Orbitrap only, you do not need to turn off the recirculating chiller, LC, autosampler, or data system. In this case, the shutdown procedure is completed. However, if you do not plan to operate your system for an extended period of time, you might want to turn off the recirculating chiller, LC, autosampler, and data system. ▲

## Starting Up the System after a Shutdown

To start up the LTQ Orbitrap after it has been shut down, you need to do the following:

1. Start up the instrument

2. Set up conditions for operation

### Starting Up the Instrument

**Note** The recirculating chiller and data system must be running before you start up the instrument. The instrument will not operate until software is received from the data system. ▲

Use the following procedure to start up the LTQ Orbitrap:

1. Start up the (optional) LC and autosampler as is described in the manual that came with the LC and autosampler.

2. Start up the data system and the chiller.

3. Turn on the flows of helium and nitrogen at the tanks, if they are off.

4. Make sure that the main power switch of the LTQ XL is in the On position and the electronics service switch of the LTQ XL is in the Operating position.

5. Place the main power switch at the right side of the LTQ Orbitrap in the On position.

6. Put the Vacuum Pumps switch to the ON position. See Figure 1-7 on page 1-9. The rotary-vane pumps and the turbomolecular pumps are started.

**Note** Pumping the system after a complete shut down takes hours and requires overnight baking of the system. ▲

7. Put the FT Electronics switch to the ON position. See Figure 1-7. When you place the FT Electronics switch to the ON position, the following occurs:

   a. Power is provided to all electronic boards. (The electron multiplier, conversion dynode, 8 kV power to the API source, main RF voltage, and octapole RF voltage remain off.)

   b. The internal computer reboots. After several seconds, the Communication LED on the front panel is illuminated yellow to indicate that the data system has started to establish a communication link.

   c. After several more seconds, the Communication LED is illuminated green to indicate that the data system has established a communication link. Software for the operation of the instrument is then transferred from the data system to the instrument.

   d. After 3 min, the System LED of the ion trap is illuminated yellow to indicate that the software transfer from the data system is complete and that the instrument is in Standby condition.

**Note** The Vacuum LED on the front panel of the LTQ XL is illuminated green only if the pressure in the vacuum manifold is below the maximum allowable pressure ($5\times10^{-4}$ Torr in the analyzer region, and 2 Torr in the capillary-skimmer region), and the safety interlock switch on the API source is depressed (that is, the API flange is secured to the spray shield). ▲

8. Press the Reset button on the LTQ XL to establish the communication link between LTQ XL and internal computer.

If you have an LC or autosampler, start it as is described in the manual that came with the LC or autosampler. If you do not have either, go to the topic “Setting Up Conditions for Operation“ below.

## Setting Up Conditions for Operation

Set up your LTQ Orbitrap for operation, as follows:

1. Before you begin data acquisition with your LTQ Orbitrap system, you need to allow the system to pump down for at least 8 hours. Operation of the system with excessive air and water in the vacuum manifold can cause reduced sensitivity, tuning problems, and a reduced lifetime of the electron multiplier.

**Note** The vacuum in the analyzer system can be improved by an overnight baking of the system. Refer to the topic “Baking Out the System” on page 3-4. ▲

2. Ensure that the helium pressure and nitrogen pressure are within the operational limits

    - Helium: 40 ±10 psig [2.75 ±0.7 bar, 275 ±70 kPa],

    - Nitrogen: 100 ±20 psig [6.9 ±1.4 bar, 690 ±140 kPa].

**Note** Air in the helium line must be purged or given sufficient time to be purged for normal performance. ▲

3. Select the **Display Status View** button in the Tune Plus window. Check to see whether the pressure measured by the ion gauge is $\leq 5 \times 10^{-9}$ mbar, and the pressure measured by the Pirani gauge is around 1 mbar. Compare the values of the other parameters in the status panel with values that you recorded previously.

4. Continue to set up for ESI or APCI operation as described in *LTQ Orbitrap Getting Started*.

# Resetting the System

If communication between the LTQ Orbitrap and data system computer is lost, it may be necessary to reset the system using the Reset button of the LTQ XL.

The procedure given here assumes that the LTQ Orbitrap and data system computer are both powered on and are operational. If the instrument, data system computer, or both are off, refer to topic "Starting Up the System after a Shutdown" on page 2-7.

To reset the LTQ Orbitrap, press the Reset button of the linear ion trap. See the *LTQ XL Hardware Manual* for the location of the Reset button. When you press the Reset button, the following occurs:

1. An interrupt on the mainboard of the internal computer causes the internal computer to reboot. All LEDs on the front panel are off except the Power LED.

2. After several seconds, the Communication LED is illuminated yellow to indicate that the data system and the instrument are starting to establish a communication link.

3. After several more seconds, the Communication LED is illuminated green to indicate that the data system and the instrument have established a communication link. Software for the operation of the instrument is then transferred from the data system to the instrument.

4. After 3 min, the software transfer is complete. The System LED is illuminated either green to indicate that the instrument is functional and the high voltages are on, or yellow to indicate that the instrument is functional and it is in Standby condition.

## Resetting the Tune and Calibration Parameters to their Default Values

You can reset the LTQ Orbitrap system tune and calibration parameters to their default values at any time. This feature may be useful if you have manually set some parameters that have resulted in less than optimum performance. To reset the LTQ Orbitrap tune and calibration parameters to their default values, proceed as follows:

In the Tune Plus window,

- Choose File > **Restore Factory Calibration** to restore the default calibration parameters, or
- Choose File > **Restore Factory Tune Method** to restore the default tune parameters.

**Note** Make sure that any problems you might be experiencing are not due to improper API source settings (spray voltage, sheath and auxiliary gas flow, ion transfer capillary temperature, etc.) before resetting the system parameters to their default values. ▲

# Chapter 3 User Maintenance

This chapter describes routine maintenance procedures that must be performed to ensure optimum performance of the LTQ Orbitrap.

**It is the user’s responsibility to maintain the system properly by performing the system maintenance procedures on a regular basis.**

The following topics are described in this chapter:



**Note** For instructions on maintaining the LTQ XL linear trap, refer to the *LTQ XL Hardware Manual*. For instructions on maintaining LCs or autosamplers, refer to the manual that comes with the LC or autosampler. ▲

## General Remarks

Preventive maintenance must commence with installation, and must continue during the warranty period to maintain the warranty. Thermo Fisher Scientific offers maintenance and service contracts. Contact your local Thermo Fisher Scientific office for more information. Routine and infrequent maintenance procedures are listed in Table 3-1.

**Table 3-1.** User maintenance procedures

| MS Detector Component | Procedure | Frequency | Procedure Location |
|---|---|---|---|
| Analyzer | System bakeout | If necessary (e.g. after performing maintenance work on the vacuum system) | page 3-4 |
| Rotary-vane pumps | Add oil | If oil level is low | Manufacturer's documentation |
| | Change oil | Every 3 months or if oil is cloudy or discolored | Manufacturer's documentation |
| Turbomolecular pumps | Exchange lubricant reservoir | Yearly | Manufacturer's documentation<br>page 3-6 |
| Recirculating chiller | Inspect reservoir fluid<br>Replace cooling fluid<br>Cleaning condenser | See manufacturer's documentation | Manufacturer's documentation<br>page 3-7 |

To successfully carry out the procedures listed in this chapter, observe the following:

- Proceed methodically
- Always wear clean, lint-free gloves when handling the components of the API source, ion optics, mass analyzer, and ion detection system.
- Always place the components on a clean, lint-free surface.
- Always cover the opening in the top of the vacuum manifold with a large, lint-free tissue whenever you remove the top cover plate of the vacuum manifold.
- Never overtighten a screw or use excessive force.
- Dirty tools can contaminate your system. Keep the tools clean and use them exclusively for maintenance and service work at the LTQ Orbitrap.
- Never insert a test probe (for example, an oscilloscope probe) into the sockets of female cable connectors on PCBs.

## Returning Parts

In order to protect our employees, we ask you for some special precautions when returning parts for exchange or repair to the factory. Your signature on the Repair Covering letter confirms that the returned parts have been de-contaminated and are free of hazardous materials. Refer to topic "Safety Advice for Possible Contamination" on page vii for further information.

## Cleaning the Surface of the Instrument

Clean the outside of the instrument with a dry cloth. For removing stains or fingerprints on the surface of the instrument (panels, for example), slightly dampen the cloth (preferably made of microfiber) with distilled water.

**Caution** Prevent any liquids from entering the inside of the instrument. ▲

## Baking Out the System

This section provides information and help concerning the system bakeout of the LTQ Orbitrap. The bakeout procedure removes unwanted gases or molecules (collected or remaining) from the high vacuum region of the instrument. Ions can collide with those gases or molecules resulting in lower overall sensitivity. Therefore, we recommend to bakeout the instrument if the high vacuum decreases noticeable during routine operation.

Bakeout is mandatory after maintenance or service work is performed in the analyzer region where the system is vented.

**Note** Pumping down the system after venting takes at least 8 hours, and usually requires overnight baking of the system. ▲

In case the system has been vented during a power failure, it is necessary to bakeout the system to obtain the operating vacuum. Refer to the topic ”Behavior of the System in Case of a Main Failure” on page 2-2.

### Bakeout Procedure

Use the following procedure to perform a system bakeout:

1. Place the system in standby condition as described in the section ”Placing the System in Standby Condition” on page 2-4.

2. Put the FT Electronics switch at the power control panel into the ON position. See Figure 1-7 on page 1-9.

3. Set the bakeout time by entering the desired time (hh:mm) with the up/down keys of the bakeout timer. See Figure 3-1.

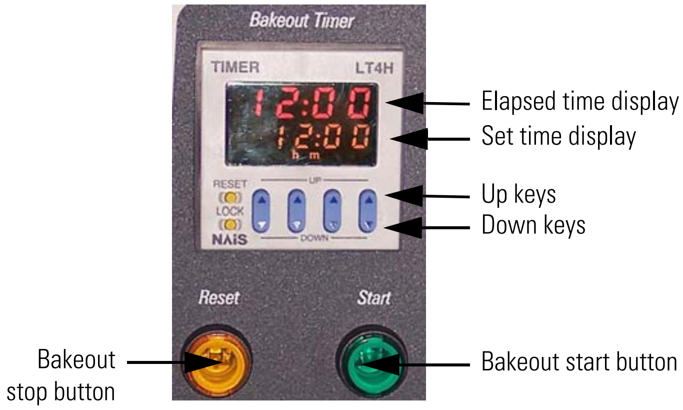


**Figure 3-1.** Bakeout timer


4. Start the bakeout procedure by pressing the green start button on the right. The LTQ Orbitrap indicates a running bakeout procedure by the flashing Vacuum and System LEDs on the front side of the instrument. See Figure 1-4 on page 1-6.


   You can stop a running bakeout procedure by pressing the orange reset/ stop button on the left side. Also press this button after you have changed the preset bakeout time.

5. The baking procedure is terminated because of two reasons:

   - The preset duration has expired, or
   - The vacuum has risen above a preset value.

The termination of the baking process is indicated by the status LEDs (System + Vacuum) on the front side that have stopped flashing.

## Maintaining the Vacuum System

The turbopumps[1] need maintenance work that is briefly outlined below.

**Note** The manuals of the pump manufacturers give detailed advice regarding safety, operation, maintenance, and installation. Please note the warnings and precautions contained in these manuals! ▲

### Exchanging the Lubricant Reservoir of the Turbopumps

**For all manipulations at the pumps, note the advice, warnings, and cautions contained in the pump manuals!**

For the turbopumps, we recommend exchanging the lubricant reservoir in a one-year cycle. At each exchange procedure, the complete lubricant reservoir must be exchanged!

**Note** The storage stability of the lubrication oil is limited. The specification of durability is given by the pump manufacturer. (Refer to the manuals for the turbopumps.) ▲

Replacements for the turbopump lubricant reservoirs (TMH 071 P: P/N 017 2350; TMU 262: P/N 105 0160) are available from Thermo Fisher Scientific.

The disposal of used oil is subject to the relevant regulations.

[1]For maintenance of the forepumps, refer to the *LTQ XL Hardware Manual* or the pump manufacturer's manual.

## Maintenance of the Recirculating Chiller

For the NESLAB Merlin M-33 recirculating chiller, the following checks should be carried out on a regular basis.

**Note** For further information and maintenance instructions, refer to the manufacturer's manual supplied with the instrument. ▲

### Reservoir

Periodically inspect the fluid inside the reservoir. If cleaning is necessary, flush the reservoir with a cleaning fluid compatible with the circulating system and the cooling fluid.

The cooling fluid should be replaced periodically. Replacement frequency depends on the operating environment and amount of usage.

**Warning** Before changing the operating fluid make sure it is at safe handling temperature. ▲

### Strainer

The Merlin recirculating chiller installed in the cooling circuit of the instrument is equipped with either an internal or external strainer, which needs to be cleaned on a regular basis.

#### Maintenance Intervals

After initial installation, the strainer may become clogged with debris and scale. Therefore, the strainer must be cleaned after the first week of installation. After this, the manufacturer recommends a monthly visual inspection. After several months the cleaning frequency will be established.

**Warning** Before cleaning the strainer, ensure the cooling fluid is at a safe handling temperature. Disconnect the power cord from the power supply and drain the unit. ▲

# Chapter 4 Replaceable Parts

This chapter contains part numbers for replaceable and consumable parts for the MS detector, data system, and kits. To ensure proper results in servicing the LTQ Orbitrap system, order only the parts listed or their equivalent.

For information on how to order parts, refer to the topic "Customer Support" in the *LTQ Orbitrap Preinstallation Requirements Guide*.

**Table 4-1.** Parts of the LTQ Orbitrap

| Designation | Part No. |
|---|---|
| Basic system LTQ Orbitrap* | 117 1570 |
| LTQ XL Linear trap MS system with computer | LTQ02-10000 |
| ESI probe, Ion Max source | OPTON-20011 |
| Low flow metal needle for API 2 probes | OPTON-30004 |
| Dell Laserprinter 1700 | 106 3385 |
| Recirculating chiller Neslab Merlin M-33 PD1, 50 Hz | 263125030000 |
| Recirculating chiller Neslab Merlin M-33 PD1, 60 Hz | 263116030000 |

*Module, for parts list see below.

## Parts Basic System

**Table 4-2.** Parts basic system (P/N 117 1570)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | Orbitrap Analyzer complete; with electrodes* | 118 7870 |
| 0020 | 1 | Pumping system Orbitrap* | 118 4490 |
| 0030 | 1 | Gas supply Orbitrap* | 117 7880 |
| 0040 | 1 | Mounting devices Orbitrap | 117 7890 |
| 0050 | 1 | Water supply Orbitrap* | 117 8460 |
| 0060 | 1 | Orbitrap panels | 117 2910 |
| 0070 | 1 | Electronic parts Orbitrap* | 800 0990 |
| 0090 | 1 | Orbitrap Installation Kit | 118 8120 |

*Module, for parts list see below.

## Parts Orbitrap Analyzer

**Table 4-3.** Parts Orbitrap analyzer complete; with electrodes (P/N 118 7870)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | Analyzer mechanics orbitrap; complete | 116 6100 |
| 0020 | 1 | Orbitrap-D30; complete | 116 5000 |

## Parts Pumping System Orbitrap

**Table 4-4.** Parts pumping system orbitrap (P/N 118 4490)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | Turbomolecular pump TMU262; modified | 118 4340 |
| 0020 | 2 | Turbomolecular pump; TMH 071 P | 114 1500 |
| 0040 | 1 | Water cooling for TMH 262 | 114 9140 |
| 0050 | 5 | Water cooling for TMH 071 P | 079 4742 |
| 0080 | 1 | UHV gauge IKR 270; short | 118 1380 |
| 0130 | 1 | Compact Pirani Gauge TPR280 | 115 6400 |

**Note** Two kits are available for the pumping system, comprising either all pumps, gauges, and cooling (pump kit orbitrap: P/N 117 5000) or all hoses, clamps, and gaskets (pump system orbitrap: P/N 117 5010). ▲

## Parts Gas Supply

**Table 4-5.** Parts gas supply (P/N 117 7880)*

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | Bulkhead union; 1/16”, for hose 4 x 1 (for P/N 069 1130) | 115 3660 |
| 0020 | 1 | Bulkhead union; 1/8"×1/8" | 052 3450 |
| 0030 | 3.0 m† | Hose; 4 x 1, Teflon | 069 0280 |
| 0040 | 3.5 m† | Hose; 4 x 1, polyurethane, blue | 069 1130 |
| 0050 | 0.5 m† | Capillary 1/16" ID-SS | 060 5470 |
| 0060 | 2 | Plug-in T-piece; 3 x 6mm | 112 8140 |
| 0070 | 1 | Stainless reducing union; Swagelok, 6 mm-1/16” | 117 8070 |
| 0080 | 1 | T-piece; 1/16" (SS-100-3) | 052 3550 |
| 0090 | 1 | Coupling; 1/16”, SS-100-6 | 052 4340 |
| 0100 | 3.0 m† | PEEKSIL capillary; 1/16", 500 X 0.075 mm | 118 6970 |
| 0110 | 1 | Reducer Swagelok; 1/8" x 1/16", stainless steel | 066 2880 |
| 0120 | 1 | Support jack; for hose 4 mm | 104 9620 |
| 0130 | 6 | Ferrule; 1/16" GVF/16 | 067 4800 |
| 0140 | 1 | N2 venting Orbitrap | 119 1480 |
| 0150 | 1 | Connector 1/8”, for hose OD 4 mm | 112 8680 |
| 0160 | 1 | Cap nut; 1/16”, stainless steel | 052 0880 |
| 0170 | 3.0† | Hose; 2 x 1, PTFE | 109 1650 |
| 0180 | 1 | Sleeve; Ø 6 mm | 104 7320 |

*For a schematic overview of the gas supply, refer to Figure 1-18 on page 1-23.

†Specify required length.

## Parts Water Supply

**Table 4-6.** Parts water supply (P/N 117 8460) *

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 2 | Quick coupling insert; 9.6 mm | 114 1640 |
| 0020 | 2 | Quick coupling body; 9.6 mm | 113 8960 |
| 0030 | 10 m† | Hose; 9 x 3, black, PVC | 104 9540 |
| 0040 | 4 | Hose clamp; 1-ear, 14.6 - 16.8 mm | 114 4910 |
| 0050 | 1.5 m† | Hose; 4 x 1, Teflon | 069 0280 |
| 0060 | 2 | Quick coupling insert; Delrin Acetal, NW 6.4 | 118 5030 |
| 0070 | 2 | Quick coupling body; Delrin Acetal, NW 6.4 | 118 5020 |
| 0080 | 16 | Clamping piece 8/16 | 037 0130 |
| 0090 | 2 | Adaptor hose nipple; male, 1/2 x 10 | 118 5840 |
| 0100 | 1 | Flow control sensor | 119 1740 |

*For a schematic overview of the cooling water circuit, refer to Figure 1-20 on page 1-25.

†Specify required length

## Electronic Parts

**Table 4-7.** Electronic parts LTQ Orbitrap (P/N 800 0990)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0030 | 1 | LTQ Orbitrap Electronics; right panel* | 208 1010 |
| 0040 | 1 | LTQ Orbitrap Electronics; left panel* | 208 1020 |
| 0050 | 1 | Electronics analyzer LTQ Orbitrap* | 208 1030 |
| 0060 | 1 | Electronics main supply LTQ Orbitrap* | 208 1040 |
| 0070 | 1 | Electronics rear panel assembly LTQ Orbitrap | 208 1050 |
| 0080 | 1 | Cable kit LTQ Orbitrap | 208 1060 |

*Module, for parts list see below.

## Electronics - Right Panel

The following replaceable parts are available for the electronics at the right panel of the LTQ Orbitrap.

**Table 4-8.** LTQ Orbitrap electronics; right panel (P/N 208 1010)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | Power supply 1 | 205 5810 |
| 0020 | 1 | Power supply 29V/2A | 206 4040 |
| 0030 | 1 | Power distribution | 206 2130 |
| 0040 | 1 | Unit PS 24V/20A | 208 1130 |
| 0050 | 1 | Unit PS +/-15V/2.75A | 208 1140 |
| 0060 | 1 | KIT E_RIGHT PANEL ASSEMBLY | 206 9790 |
| 0070 | 1 | Unit data acquisition* | 206 4132 |
| 0080 | 1 | LP Instrument control board | 205 4221 |
| 0085 | 1 | LP CLT RF TRIGGER | 208 5880 |
| 0090 | 1 | LP LT ANALOG INTERFACE LTQ Orbitrap | 208 1940 |
| 0100 | 1 | LP LT DIGITAL INTERFACE | 208 7180 |
| 0110 | 1 | UNIT PS-BASIC LOAD | 208 5900 |

*Module, for parts list see below.

**Table 4-9.** Parts unit data acquisition (P/N 206 4132)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | Housing PC2 FTMS / ORBITRAP | 115 5320 |
| 0020 | 1 | Network interface card LCS 8038 TXR | 208 2140 |
| 0030 | 1 | MATRIX-STL FRONTEND-PC LTQ-FT | 207 6470 |
| 0040 | 1 | UNIT_PC POWER SUPPLY PS_ON | 209 5950 |
| 0050 | 1 | LP DAQ DIGITAL PCI BOARD | 206 0501 |
| 0060 | 1 | IDC/26POL/1.1M | 203 0340 |
| 0070 | 1 | DAQ ANALOG FRONT END | 206 4150 |

**Table 4-9.** Parts unit data acquisition (P/N 206 4132), continued

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0080 | 3 | SMB BU-90ø/ST-0ø/0.7M | 205 9630 |
| 0090 | 1 | IDC/14POL/0.12M | 206 3790 |
| 0100 | 2 | IDC/40POL/0.10M | 205 2190 |
| 0110 | 1 | PS2/DAQ ANALOG | 205 9710 |
| 0120 | 1 | POWER SUPPLY 2 | 206 1440 |
| 0130 | 1 | Load resistor 4R7 | 206 5230 |
| 0140 | 1 | Angle bracket, for PC | 121 8680 |

## Electronics - Left Panel

The following replaceable parts are available for the electronics at the left panel of the LTQ Orbitrap.

**Table 4-10.** LTQ Orbitrap Electronics; left panel (P/N 208 1020)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | UNIT HIGH VOLTAGE PS | 207 7990 |
| 0020 | 1 | UNIT CENTRAL ELECTRODE PS | 207 9610 |
| 0030 | 1 | LP SPI-BUS-TERMINATION | 208 1480 |

## Electronics Analyzer

The following replaceable parts are available for the electronics at the analyzer of the LTQ Orbitrap.

**Table 4-11.** Electronics analyzer LTQ Orbitrap (P/N 208 1030)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | UNIT CLT RF SUPPLY | 207 9580 |
| 0020 | 1 | UNIT CENTRAL ELECTRODE PULSER | 207 9640 |
| 0030 | 1 | UNIT TEMPERATUR CONTROLLER | 207 8930 |
| 0040 | 1 | UNIT PRE AMPLIFIER | 207 8900 |
| 0050 | 1 | UNIT ION OPTIC SUPPLY | 208 1340 |

## Electronics Main Supply

The following replaceable parts are available for the electronics main supply of the LTQ Orbitrap.

**Table 4-12.** Electronics main supply LTQ Orbitrap (P/N 208 1040)

| Pos. No. | Qty. | Designation | Part No. |
|---|---|---|---|
| 0010 | 1 | UNIT SWITCH PANEL | 208 1120 |
| 0020 | 1 | KIT IEC CONNECTOR | 209 6110 |
| 0040 | 1 | KIT BAKEOUT-SWITCHES | 207 9040 |
| 0050 | 1 | Cable loom, mains supply | 208 1110 |
| 0120 | 1 | Cable loom, power distribution/bakeout timer | 207 9010 |
| 0130 | 1 | UNIT BAKEOUT TIMER | 208 0960 |

# Glossary

This section lists and defines terms used in this manual. It also includes acronyms, metric prefixes, symbols, and abbreviations.

**A** ampere

**ac** alternating current

**ADC** analog-to-digital converter

**AGC™** Automatic Gain Control

**AP** acquisition processor

**APCI** atmospheric pressure chemical ionization

**API** atmospheric pressure ionization

**ASCII** American Standard Code for Information Interchange

**b** bit

**B** byte (8 b)

**baud rate** data transmission speed in events per second

**°C** degrees Celsius

**CAN bus** Controller Area Network

**cfm** cubic feet per minute

**CI** chemical ionization

**CLT** curved linear trap

**cm** centimeter

**$cm^3$** cubic centimeter

**CPU** central processing unit (of a computer)

**CRC** cyclic redundancy check

**CRM** consecutive reaction monitoring

**<Ctrl>** control key on the terminal keyboard

**d** depth

**Da** dalton

**DAC** digital-to-analog converter

**dc** direct current

**DDS** direct digital synthesizer

**DS** data system

**DSP** digital signal processor

**EI** electron ionization

**EMBL** European Molecular Biology Laboratory

**<Enter>** Enter key on the terminal keyboard

**ESD** electrostatic discharge

**ESI** electrospray ionization

**eV** electron volt

**f** femto ($10^{-15}$)

**°F** degrees Fahrenheit

***.fasta* file** extension of a SEQUEST™ search database file

**front end** internal computer

**ft** foot

**FFT** Fast Fourier transformation

**FT** Fourier Transformation

**FTMS** Fourier Transformation Mass Spectroscopy

**FTP** file transfer protocol

**FWHM** Full Width at Half Maximum

**g** gram

**G** Gauss; giga ($10^9$)

**GC** gas chromatograph; gas chromatography

**GC/MS** gas chromatograph / mass spectrometer

**GUI** graphical user interface

**h** hour

**h** height

**HPLC** high-performance liquid chromatograph

**HV** high voltage

**Hz** hertz (cycles per second)

**ICIS™** Interactive Chemical Information System

**ICL™** Instrument Control Language™

**ID** inside diameter

**IEC** International Electrotechnical Commission

**IEEE** Institute of Electrical and Electronics Engineers

**in** inch

**I/O** input/output

**k** kilo ($10^3$, 1000)

**K** kilo ($2^{10}$, 1024)

**KEGG** Kyoto Encyclopedia of Genes and Genomes

**kg** kilogram

**l** length

**L** liter

**LAN** local area network

**lb** pound

**LC** liquid chromatograph; liquid chromatography

**LC/MS** liquid chromatograph / mass spectrometer

**LED** light-emitting diode

**μ** micro ($10^{-6}$)

**m** meter

**m** milli ($10^{-3}$)

**M** mega ($10^6$)

**$M^+$** molecular ion

**MB** Megabyte (1 048 576 bytes)

**$MH^+$** protonated molecular ion

**min** minute

**mL** milliliter

**mm** millimeter

**MS** mass spectrometer; mass spectrometry

**MS** $MS^n$ power: where n = 1

**MS/MS** $MS^n$ power: where n = 2

**$MS^n$** $MS^n$ power: where n = 1 through 10

**m/z** mass-to-charge ratio

**n** nano ($10^{-9}$)

**NCBI** National Center for Biotechnology Information (USA)

**NIST** National Institute of Standards and Technology (USA)

**OD** outside diameter

**Ω** ohm

**p** pico ($10^{-12}$)

**Pa** pascal

**PCB** printed circuit board

**PE** protective earth

**PID** proportional / integral / differential

**P/N** part number

**P/P** peak-to-peak voltage

**ppm** parts per million

**psig** pounds per square inch, gauge

**RAM** random access memory

**RF** radio frequency

**RMS** root mean square

**ROM** read-only memory

**RS-232** industry standard for serial communications

**s** second

**SIM** selected ion monitoring

**SPI** Serial Peripheral Interface

**SRM** selected reaction monitoring

**TCP/IP** transmission control protocol / Internet protocol

**TIC** total ion current

**Torr** torr

**u** atomic mass unit

**UHV** ultra high vacuum

**V** volt

**V ac** volts alternating current

**V dc** volts direct current

**vol** volume

**w** width

**W** watt

# Index

## Numerics



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