LASER ZENTRUM HANNOVER e.V.

User Guide

Enhanced LIGO MOPA

Observatory Laser

Index

1 Scope of supply

- MOPA Laser head

- Diode Box (**DB**) including
  - 4 fiber coupled laser diodes Jenoptik JOLD CPXF–45–1L with a nominal output power of 45 W
  - Interlock cable to CB
  - External interlock cable

- Laser Control Box (**CB**) with touchscreen including
  - MOPA diag. cable
  - Diag. 1 cable to NPRO driver
  - Diag. 2 cable to NPRO driver
  - Interlock cable to NPRO driver
  - External interlock cable
  - 24 V cable to laser head

- Water chiller for cooling of amplifier head and Laser Diode cooling plate
  - Diag. cable to DB

- NPRO driver including
  - Laser cable (13 m)
  - Power cable

2 Safety

This laser is a class 4 laser system and emits invisible radiation at a wavelength of 1064 nm.

Avoid eye or skin exposure to direct or scattered radiation. Materials exposed to the radiation may suffer thermal damage. Exposure of flammable material to the radiation is a major fire hazard.

The laser must be operated by trained personnel only. The use of suitable eye protection against the emission of 808 nm and 1064 nm is required for all personnel in the room the laser is operated in.

Read the manual carefully before installing and operating the laser.

The laser is delivered with the mechanical shutter of the master oscillator closed. For initial startup follow the alignment procedures as described in Chapter 7 and 8.

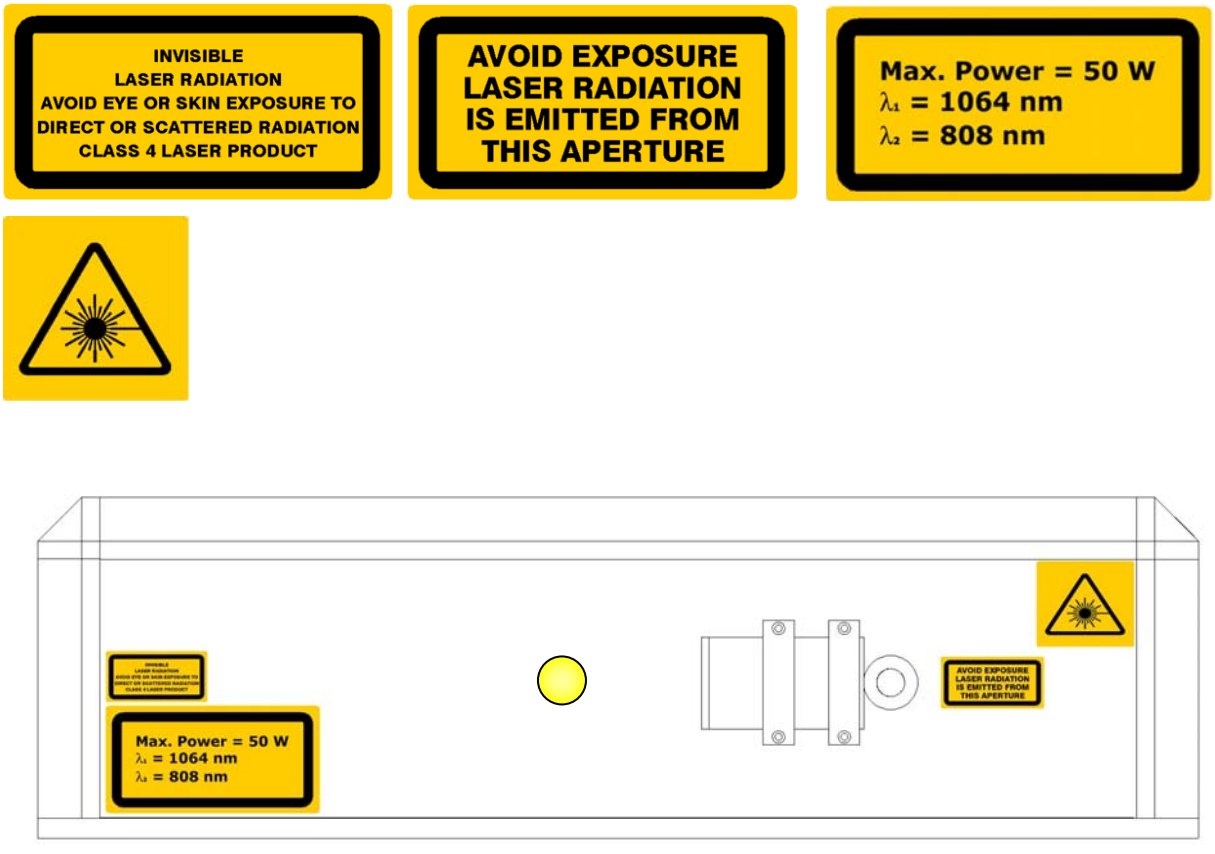

Figure 2-1: Placement of the Laser warning signs

3 General Description of the Laser System

This laser is a Master Oscillator Power Amplifier system which consists of a non-planar-ring-oscillator (NPRO) and a four-stage amplifier. The system emits single-frequency radiation at 1064 nm at power levels of 35 W.

The laser system is developed for scientific use only!

3.1 Overview of the laser system

In figure 3.1 an overview of the laser system is shown. The MOPA system consists of a 2 W NPRO and a four stage amplifier. The laser mode of the NPRO is mode matched by some coupling optics to the pump-mode sizes of the amplifier. An Isolator protects the NPRO against back reflections. The laser diode box (DB) includes 4 fiber coupled laser diodes to pump the amplifier. Each laser diode is temperature controlled by the Control Box (CB). The control box also controls the whole laser system in terms of diode current, NPRO operation and includes also software interlocks for over temperature and output power controlling. A water chiller takes over the heat dissipated by the laser diodes and the laser crystals. A further and more detailed description of the laser system and all sub components is given in the following sections.

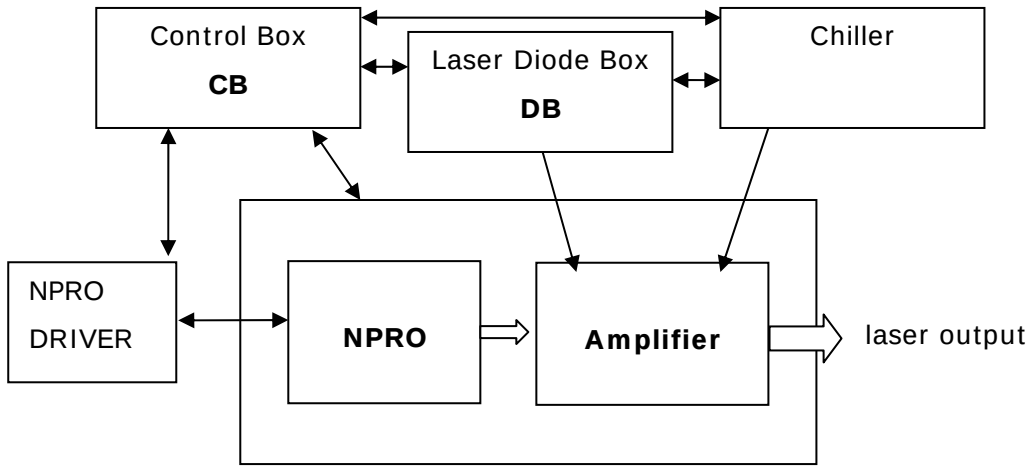

Figure 3-1: MOPA System overview

3.2 System Connections

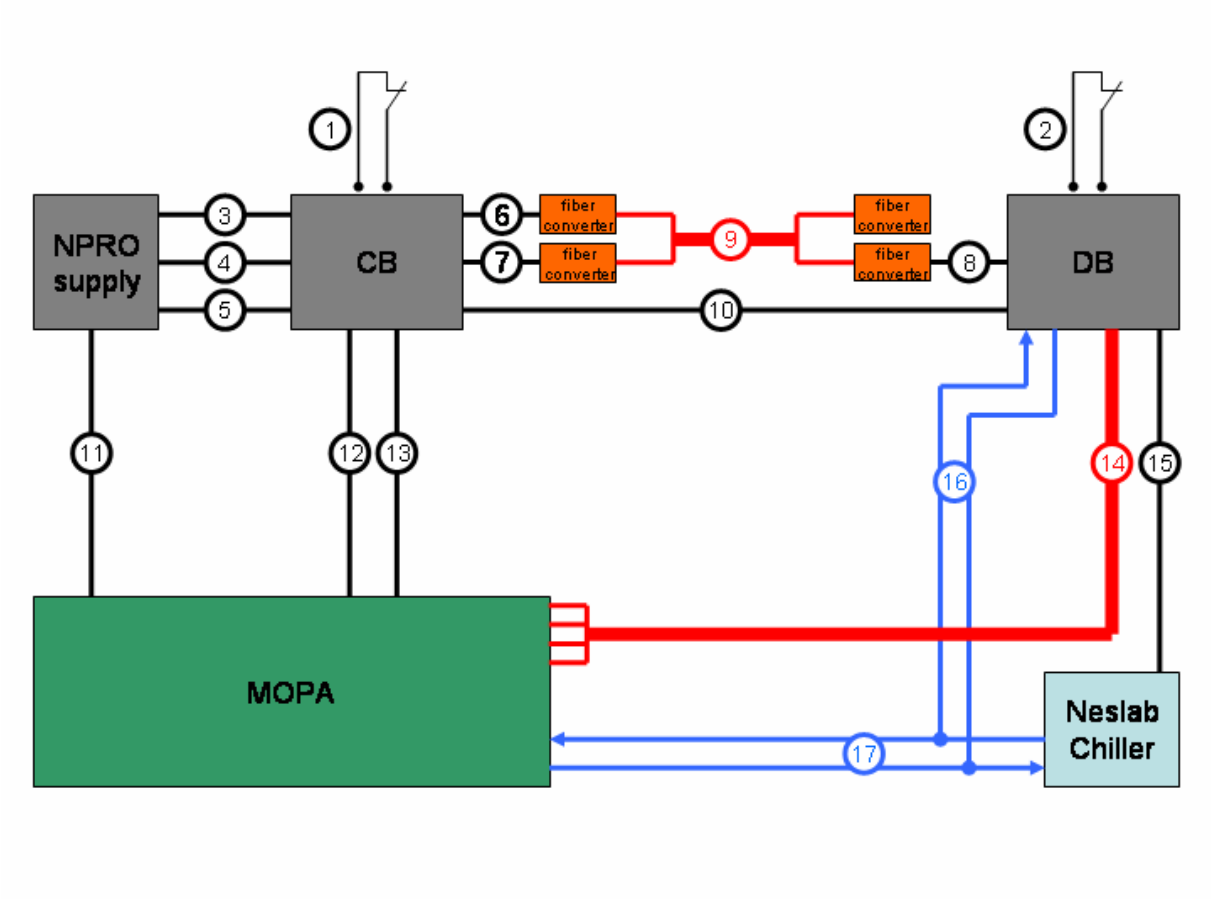

Figure 3-2: System connections

Description

(1) CB interlock Binder connector, male, part no. 99-0401-00-02

(2) DB interlock Binder connector , male, part no. 99-0401-00-02

(3) To NPRO interlock 2m twisted pair, 2x0.25mm, Binder connector, male, part no. 99-0401-00-02

(4) NPRO Diag 1 2m 25pin sub d connector, male – female

(5) NPRO Diag 2 2m 25pin sub d connector, male – female

(6) Ethernet – 1m CAT-5 cable, RJ45 connector to fiber converter

(7) EtherCAT – 1m CAT-5 cable, RJ45 connector to fiber converter

(8) EtherCAT - 1m CAT-5 cable, RJ45 connector to fiber converter

(9) Communication Fiberbundle – 8x 100m fiber 50/125u, Connector SC-SC, OM2

(10) Interlock COM – 100m cable, 2 twisted pairs, 4x0.25mm^2 to 5 pin male Binder connector

(11) NPRO laser cable - 13 m 37 pin sub d connector, male - female

(12) Amp Diag - 13m 25 pin sub d connector, male – female

(13) MOPA Diag - 13m 25 pin sub d connector, male – female

(14) Laser fiber bundle – 6x 75m fiber for L1 and H1, 6x 100m for H2, 400um, N.A. 0.22, metal shielded, SMA connectors

(15) Chiller Diag - 30m 15 pin sub d connector, male – male

(16) Cooling water hose – XX m, 8 mm inner dia, 10 mm outer dia, polyurethane, Y connector

(17) Cooling water hose – XX m, 8 mm inner dia, 10 mm outer dia, polyurethane

4 MOPA laser head

This section describes the laser head. The MOPA laser head includes the NPRO as master oscillator, one EOM , one AOM, a faraday isolator to protect the master oscillator from back reflections, optics for beam shape and polarization control and the amplifier head. In Figure 4-1 a picture of the MOPA laser head is shown.

Figure 4-1: MOPA laser head

4.1 Optical layout of the MOPA laser head

In the following section the beam path beginning from the NPRO to the amplifier will be described. A scheme of the MOPA laser head is shown in Figure 4-2. The beam waist inside the NPRO is located 9 cm in front of the shutter and has a diameter of 350 - 400 µm. First, the circular output polarization of the master oscillator is linearized by a quarter-wave plate, a half-wave plate and a polarization beamsplitter cube. Behind the beamsplitter the beam is vertically polarized with respect to the breadboard. With lens L1 (BK7, f=100 mm) the beam is collimated and adapted to the following EOM. Behind this EOM is space left to install a second EOM if needed. In this case the mode matching for the amplifier might be adjusted to make up for changes in the beam caustic. The second lens L2 (BK7, f=100 mm) is used to produce a waist slightly behind the AOM to match the aperture of the AOM. The first-order of the AOM is absorbed in the beam dump.
The remotely controllable shutter can be used to block the seed laser beam.
The half-wave plate sets the polarization for the faraday isolator. For alignment purposes the power behind the isolator can be attenuated by rotating this half-wave plate without changing the caustic of the beam. The isolator is adjusted that way that the transmitted

beam is still polarized vertically with respect to the breadboard.. L3 collimates the beam for the mode matching witch is done by lenses L4 (FS, biconcave, f=-166 mm @ 1064 nm) and L5 (BK7, f= 150 mm).

For best amplifier performance a focus with a radius of 130 - 170 µm hast to be created 20 – 40 mm inside the amplifier head. The laser is then amplified in the amplifier head to a output power of 35 W.

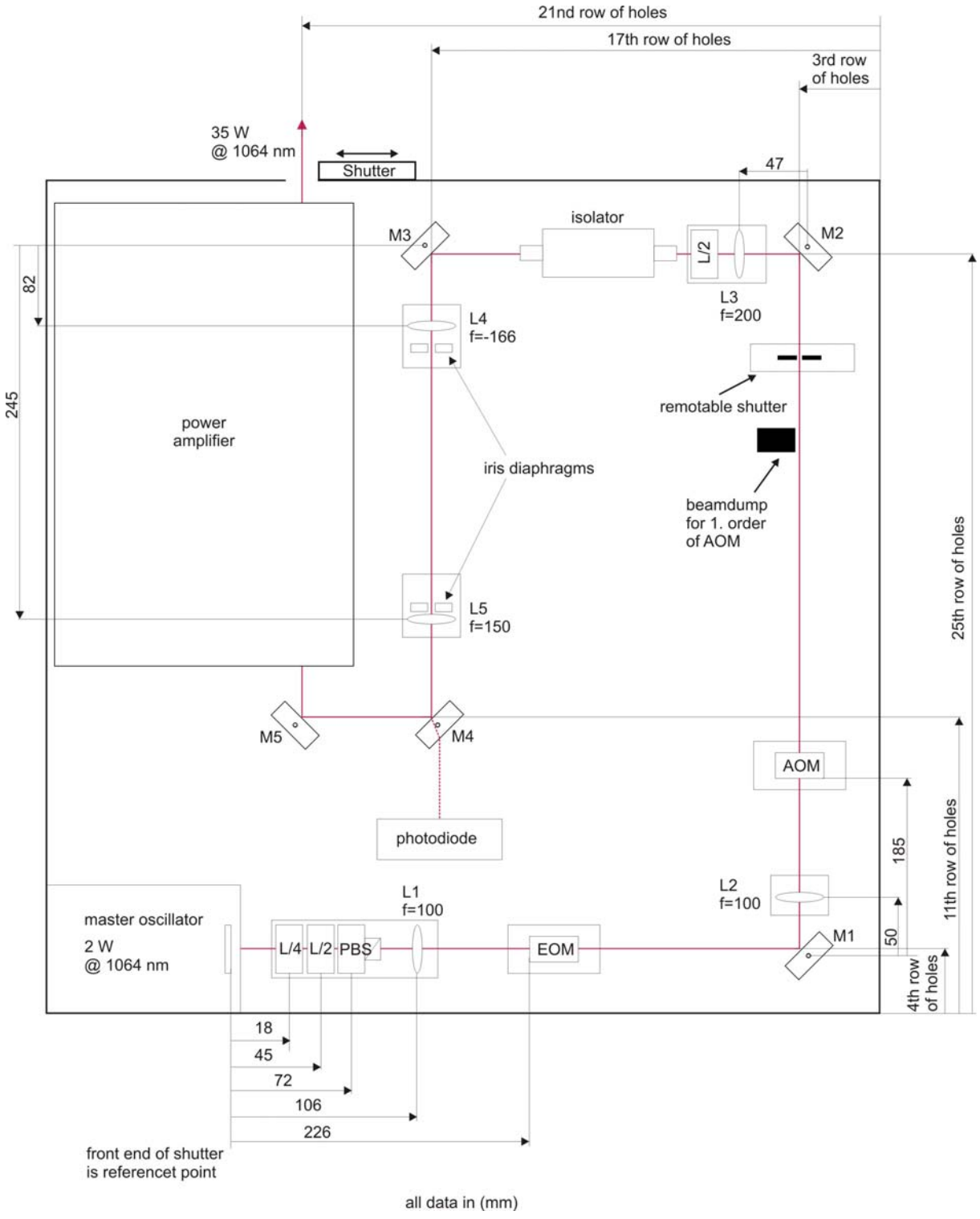

Figure 4-2: MOPA scheme

Figure 4-3 shows the connections of the MOPA laser head. Starting on the right hand side you can see the NPRO cable and the cable for the AOM. Then there are on the top the fibers for diodes 1 to 4 and on the bottom the water hoses and the diagnostics cable

for the analog signals of the optical pickups and the temperature monitor for the crystal holders.

Figure 4-3: MOPA connections

4.2 Master Oscillator

The master oscilllator used in this MOPA system is an Innolight MEPHISTO 2000 NE LIGO. This laser is a non-planar ring oscillator with an output power of 2000 mW, Noise-Eater and in addition to the standard version a diagnostics output. The beam waist of the master laser at nominal operation is typically 350 – 400 µm diameter and is located 90 mm inside the NPRO housing with respect to the front.
Additional information can be found in the manual in the appendix.

4.3 Amplifier head

The amplifier head consists of 4 Nd:YVO_4 amplifier stages pumped longitudinally by fiber coupled diode lasers. Amplification is done by a single pass of the laser beam through each amplifier stage. A scheme of the amplifier can be seen in in Figure 4-4.

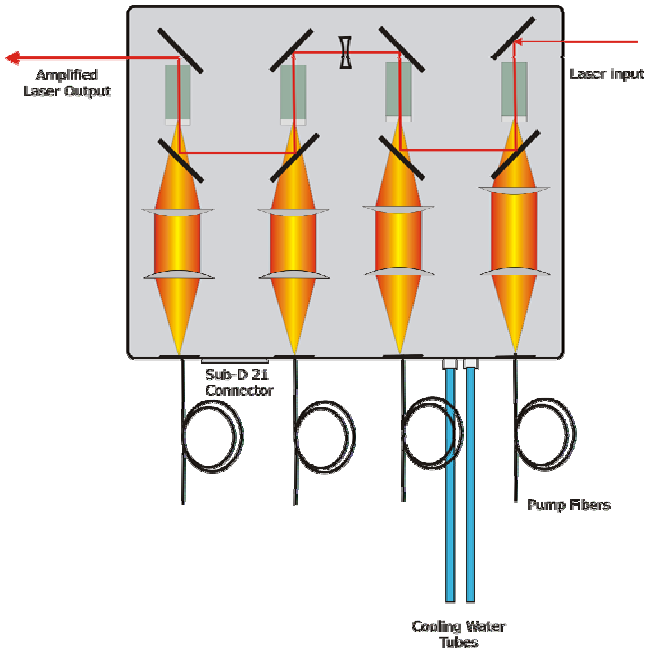

Figure 4-4: Amplifier head scheme

4.3.1 Amplifier crystals

The used amplifier crystals have overall dimensions of 3x3x10 mm. At the side where the pump beam enters the crystal is a 2 mm undoped YVO_4 end cap diffusion bonded to the 0.3 at. % Nd doped 8 mm long active crystal. An example data sheet of the the crystals can be found in the appendix.

The crystals are wrapped into 0.5 mm thick indium foil and press fitted into the water cooled crystal holder. The amplifier is equipped with two crystal holders which each hold two crystals. Since the cooling water successively runs through both crystal holders one PT100 temperature sensor is used to monitor proper cooling of all crystals. In case the crystals holder temperature rises over 35° C e. g. because of not connected or too heavily bend water tubes an interlock is triggered and the system switches off.

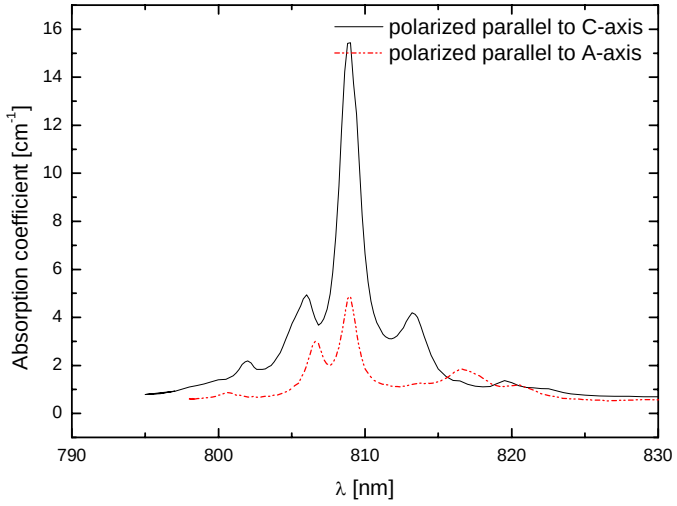

Figure 4-5: Absorption spectrum of Nd:YVO_4

Nd:YVO_4 is an optically anisotropic crystal and naturally birefringent. As shown in Figure 4-5 the absorption of Nd:YVO_4 is polarization dependent. The gain of Nd:YVO_4 is also polarization dependent and efficient amplification only takes place for laser beam polarized parallel to the C-axis of the crystal. The crystals are orientated with their C-axis vertical to the table. For this reason the polarization of the input beam needs to be vertical to the table.

4.3.2 Pumping of the amplifier crystals

The used pump-diodes are Jenoptic JOLD-45-CPXF-1L with a wavelength of 808 nm and a maximum output power of 45 W. The diodes are driven at an output power of appr. 33 W at 48A. The fibers have a diameter of 400 µm and an NA of 0.22. The pump beam emitted from the fibers is collimated by a f=40 mm lens in each stage. In the first amplifier stage a f=60 mm lens images the fiber into the crystal to create a 600 µm diameter pump spot. In the other 3 stages a f=80 mm lens is used to create a pump spot of 800 µm diameter. All mirrors used inside the amplifier are high transmitting for the 808 nm pump radiation and high reflective for the 1064 nm laser radiation at an angle of incidence of 45°. The laser crystals transmit appr. 10 % of the pump light which is then absorbed by the amplifier housing.

4.3.3 Fibers

The fibers supplied are from FiberTech GmbH and have a core diameter of 400 µm and a numerical aperture of 0.22. The fibers have an overall length of 12 m. Approximately 2 m of the fiber are inside the Diode box and are wound up for mode mixing. The 10 m outside the box are metal armored. The fiber has F-SMA-Connectors on both ends.

4.3.4 Laser beam modematching

For optimum output power and beam quality the laser beam has to be matched to the pumped volume in the amplifier crystals. In order to maintain the beam quality of the seed laser it is important that the laser beam is smaller than the pumped volume. The laser is matched to the pumped volume of the crystals by creating a focus of 150 µm radius 60 mm in front of the first crystal which is apppr. 30mm inside the amplifier housing. The first thermal lens adapts the beam for the second crystal. The second thermal lens is then compensated by a biconcave lens with a focal length of f=-166 mm at 1064 nm. The beam propagates tthrough stage 3 and 4 in a similar way (Figure 4-6).

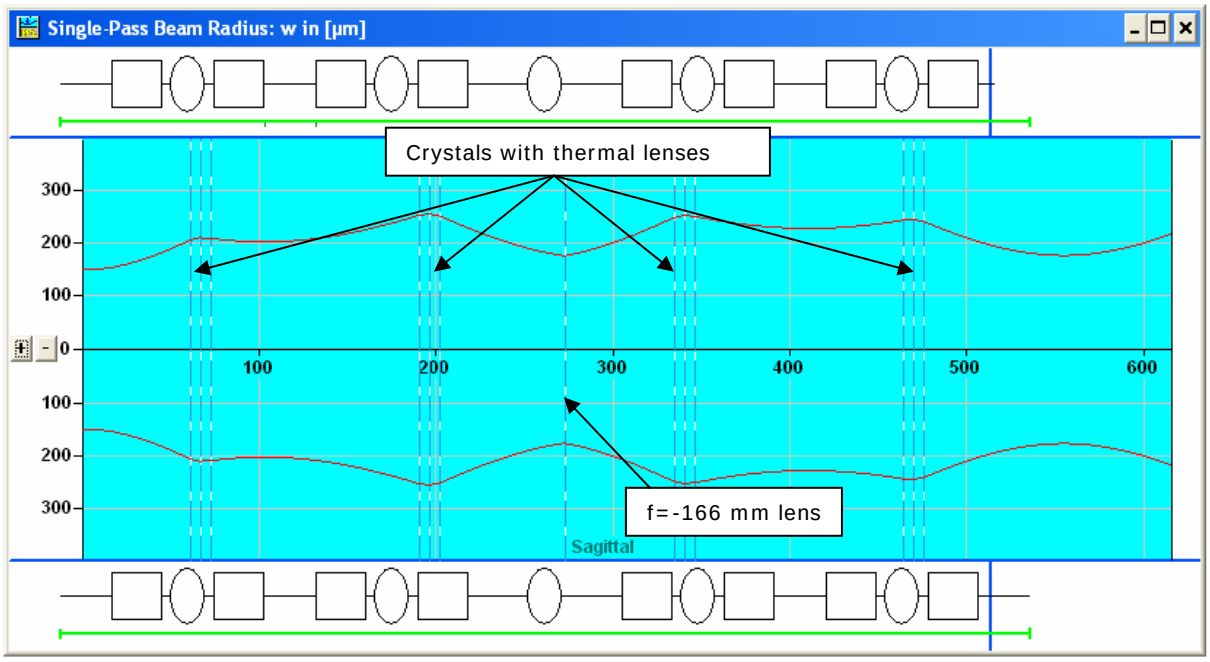

Figure 4-6: Beam radius inside the amplifier head

4.4 Amplification

The output power depends on the saturation of the amplifier by the input laser beam.

At lower input powers and therefore less saturation the amplification factor P_{out}/P_{in} will be higher but less laser power will be extracted from the amplifier. Figure 4-7 shows the output power of the amplifier head. The output power measurements were done with an OPHIR Nova II console and a FL300 thermal sensor head (see appendix for calibration certificates).

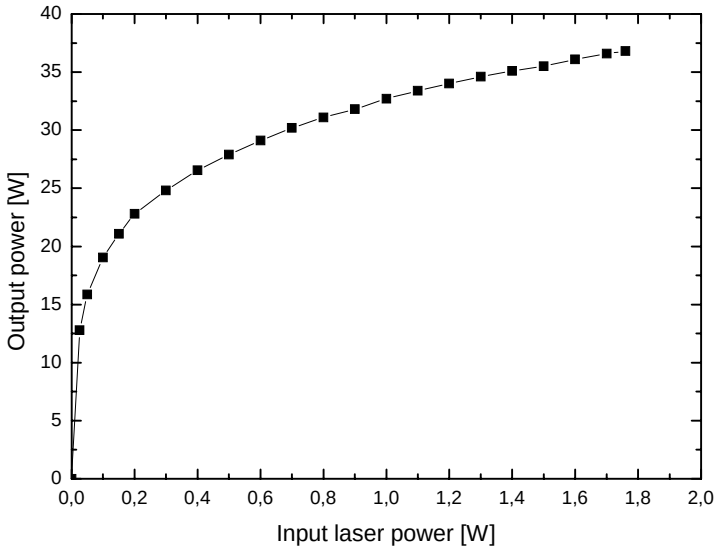

Figure 4-7: Output power of amplifier head

5 Power supply

This section describes the power supply boxes containing the interface, drivers, electronics and laser diodes.

5.1 Overview

The Power supply of the amplifier consists of two boxes: The Diode Box (**DB**) will be placed in the diode enclosure room and contains the four laser diodes, the power supplies and the safety interlock circuit. The Control Box (**CB**) will be placed in proximity to the MOPA head. It contains the NPRO and amplifier diagnostics wiring and the computer control of the laser system. The CB needs to be externally powered with 24V DC, 3A.

5.2 Connection

In this section the wiring of the system is described. The wiring should be straight-forward as all connectors are labelled with the matching socket name. Connect according to Figure 3-2

5.2.1 DB back panel

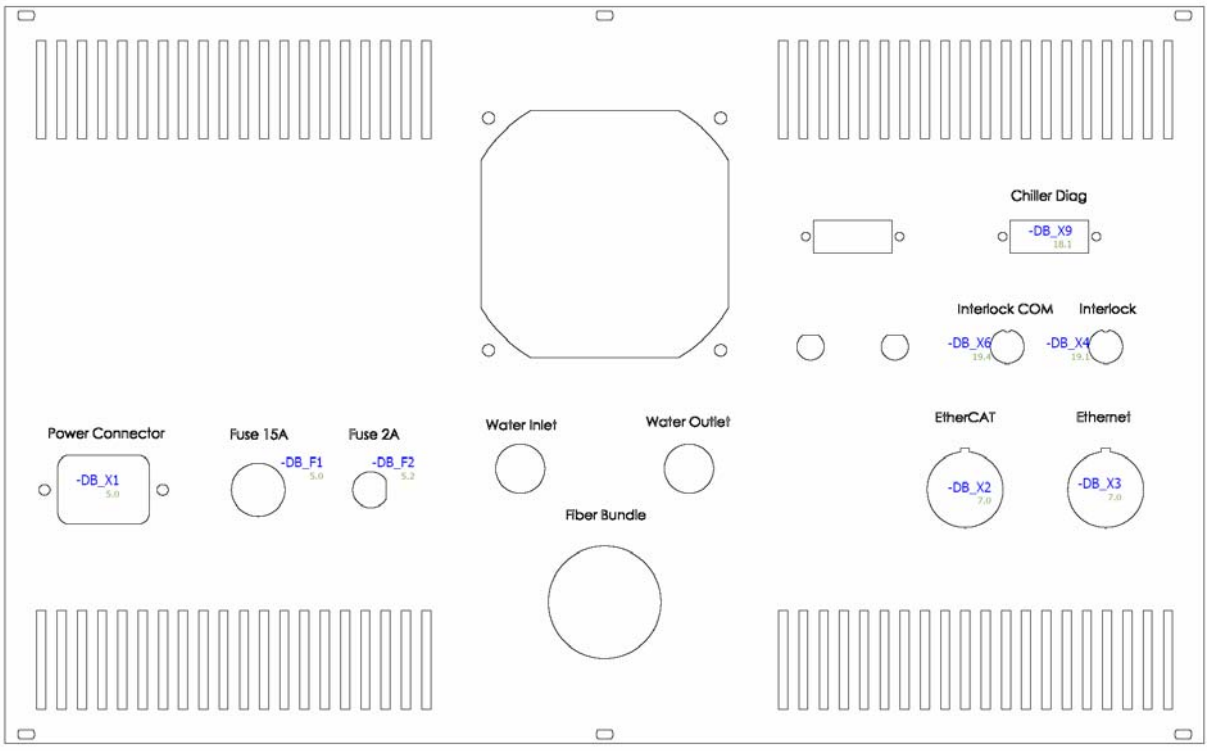

Figure 5-1: Diode Box back panel wiring

5.2.2 CB back panel

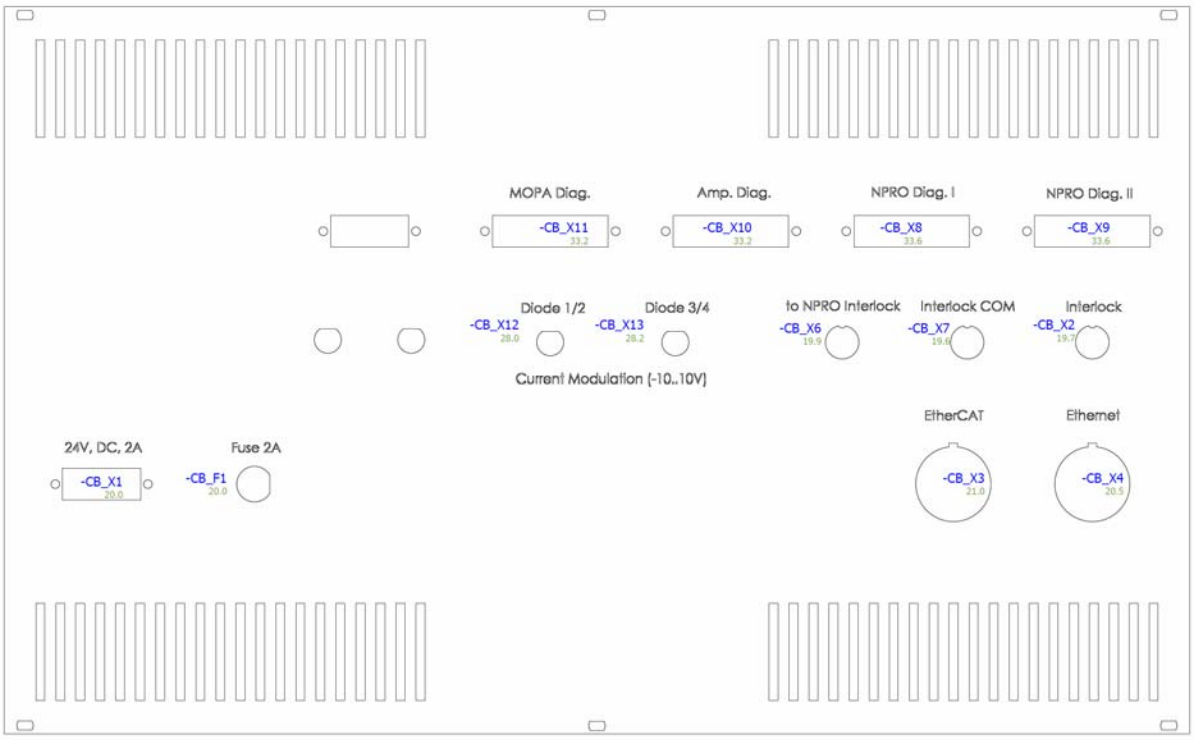

Figure 5-2: Control box back panel wiring

5.2.3 Current Modulation Connector

These connectors provide a software controlled DC current modulation up to a frequency of 5 Hz. Modulation is done with -10V...+10V. The amplitude can be set in the set menu (chapter 6.2) up to a maximum of 10% modulation of the maximum power supply current which means a maximum modulation of +-7 A.

5.2.4 NPRO power supply back panel

Figure 5-3: NPRO power supply back panel wiring

5.2.5 Chiller

Information about the chiller can be found in the chiller manual in the appendix.

The error code for relay 1 has to be programmed to 18464 which means ther relay will trigger at the following errors :

- Low flow (32)
- Unit fault (2048)
- Limit fault (16384)

These Errors will lead to a system shutdown and an error message will be displayed at the control box.

Relay 2 has to bee programmed for error code 7 which means it triggers at :

- Low level (1)
- Tank overflow (2)
- Drip pan full (4)

In case of one of these errors a warning message will be displayed and the laser will continue to run.

6 User interface

This section describes the user interface of the laser system. Navigate though the menus via touch screen.

6.1 Main menu

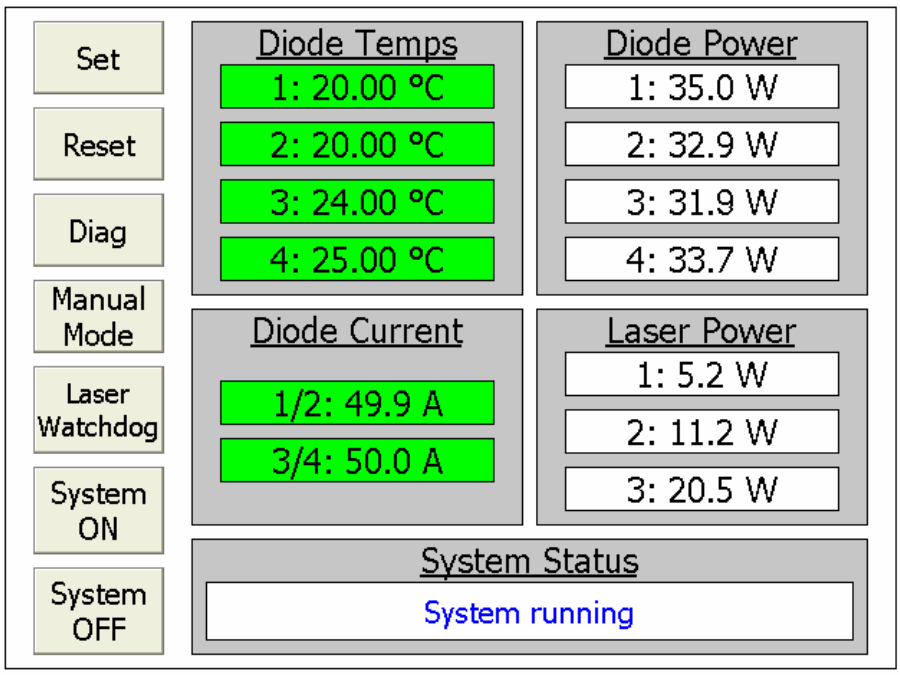

Figure 6-1: Main Menu

The main menu shows the most important actual values during laser operation.
The temperature in deg C of each diode is shown in the upper section of the menu. During operation the background of each diode temp turns green if the temperature deviates less than +/- 0.05K from the set point.
Below this section the diode current of the two power supplies can be monitored. During operation the background of the diode currents turn green when the system has reached the nominal operating current set in the set menu.
The amplifier head is equipped with 7 pick-offs to monitor the pump power of each diode and the laser power of the first three amplifier stages. These can be monitored in the right section of the menu. At the bottom of the menu actual system status messages are shown. The push-buttons on the left side are described in detail on the following pages.

Set

Enters the Set-menu to change the amplifier parameters.

Reset

Resets the system after an error has occurred.

Diag

Enters the Diag-menu where additional values can be monitored.

Manual Mode

Enters the Manual Mode menu where system parts can be switched independently.

Laser Watchdog

When this button is toggled the actual value of the laser power of amplifier stage 3 is saved. If the laser power drops more than 10% of the saved value the system is turned off and an error message is shown.

System ON

Opens the confirmation window to turn on the laser system. After the confirmation the boot sequence is started as follows. First the TECs of the laser diodes are switched on, then the system turns on the NPRO. Then the diode current is ramped to nominal diode current.

System OFF

Turns off the laser system.

6.2 Set menu

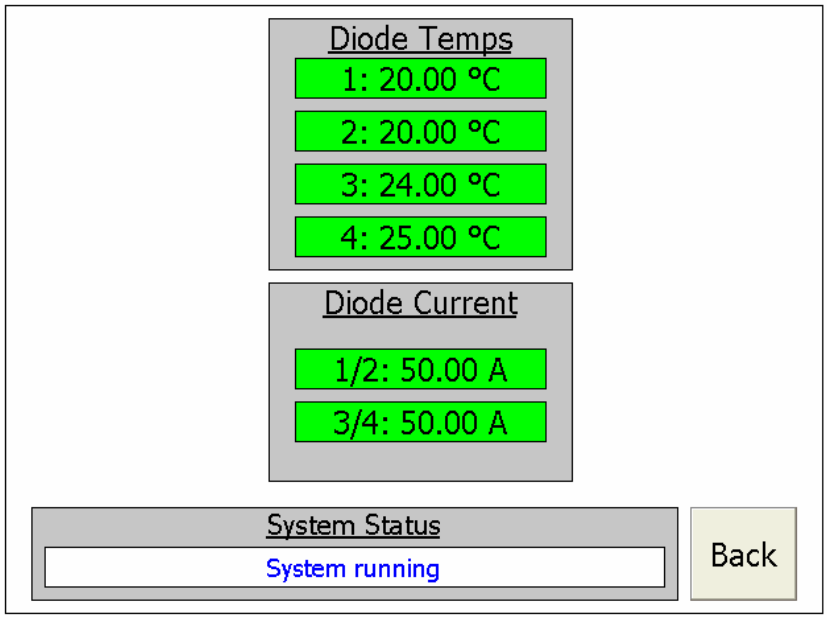

Figure 6-2: Set menu

Enter this menu to adjust the set point of temperature and current of the laser diodes. To change the values touch the parameter and a numpad will pop up. The system will accept diode temps from 15 to 34 deg C and diode currents from 0 to 60 Amperes. The **Back** button zooms back to the main menu.

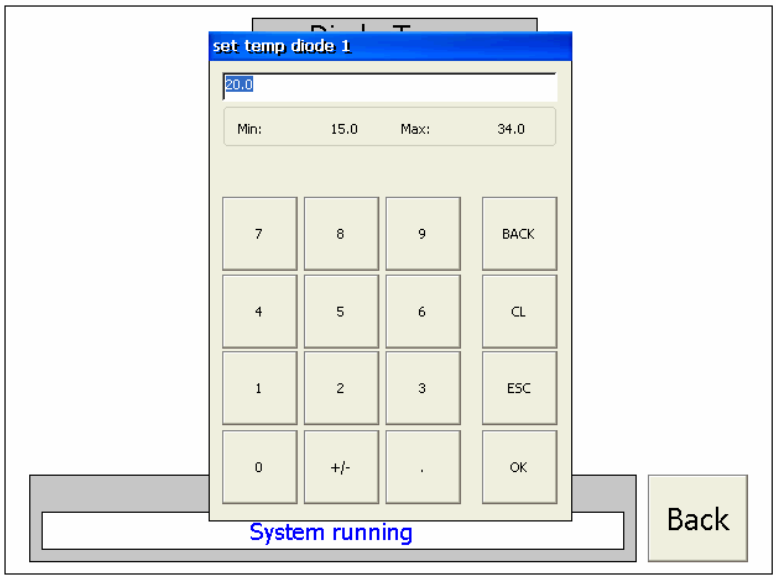

Figure 6-3: Set menu, numpad

6.3 Diag

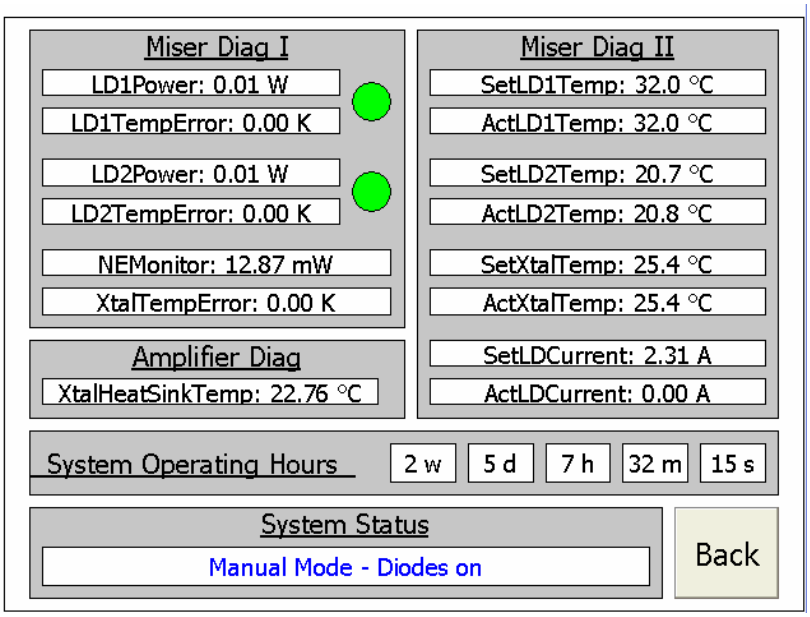

Figure 6-4: Diag menu

In the Diag menu additional parameters of the laser can be monitored. Please note that these parameters are read-only and cannot be changed. You can change the settings of the NPRO at the front panel of the NPRO power supply.
The sections are described in the following.

NPRO Diag I

LD1Power

Power monitor of laser diode 1 of the NPRO

LD1TempError

Shows the temperature deviation from the temp set point of laser diode 1 of the NPRO

LD2Power

Power monitor of laser diode 2 of the NPRO

LD2TempError

Shows the temperature deviation from the temp set point of laser diode 2 of the NPRO

NEMonitor

Noise Eater Monitor signal

XtalTempError

Shows the temperature deviation from the temp set point of the laser crystal of the NPRO

NPRO Diag II

SetLD1Temp

Set point of temperature of NPRO laser diode 1

ActLD1Temp

Actual temperature of NPRO laser diode 1

SetLD2Temp

Set point of temperature of NPRO laser diode 2

ActLD2Temp

Actual temperature of NPRO laser diode 2

SetXtalTemp

Set point of temperature of NPRO laser crystal

ActXtalTemp

Actual temperature of NPRO laser crystal

SetLDCurrent

Set point of current of laser diodes

ActLDCurrent

Actual current of laser diodes

Amplifier Diag

XtalHeatSinkTemp

Temperature of the first amplifier crystal holder.

System Operating Time

When the laser diodes are running this counter is monitoring the operating time of the system. The display is separated in weeks, days, hours, minutes and seconds.

6.4 Manual Mode

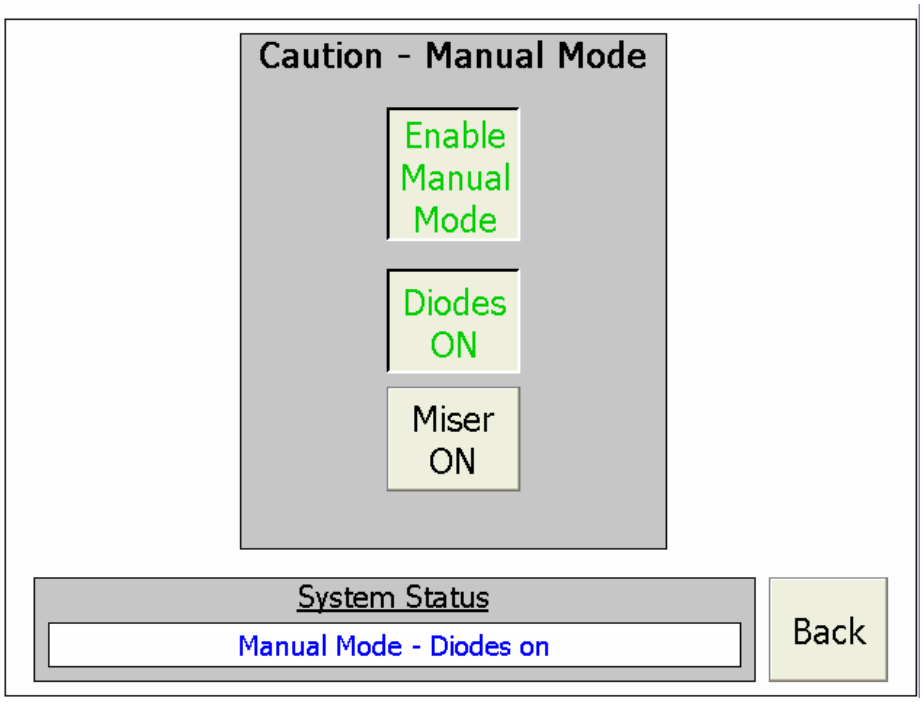

Figure 6-5: Manual Mode menu

This mode has been implemented for alignment purposes of the laser system. When the button **Enable Manual Mode** is toggled the system switches to manual mode. Now amplifier laser diodes and NPRO can be operated separately. To return to normal operating mode you can either press the **Enable Manual Mode button** or return to the main menu with button **Back** and press **System OFF**

6.5 Remote Control

A VNC server installed on the CB to allow for remote control via LAN. Use a s VNC client e. g. Ultra VNC (http://www.uvnc.com) for this.
Username: user
Password: enhLIGO

6.6 Logging

The system has been set up to log numerous variables at a 30 sec cycle (time-stamped) into \Hard Disk\FTP\ of the CF harddrive. The log-filenames are ending with a number computed by the days of the operating counter. Each day a new file is created. To prevent the CF from filling up the logfiles generated 10 days earlier will be deleted.
Current list of logged variables:

TemplogXX.txt
Temp D1 [°C]
Temp D2 [°C]
Temp D3 [°C]
Temp D4 [°C]
Temp Xtal tower [°C]
Temp DB heatsink [C°]

TecCurrentLogXX.txt
TEC current D1 [A]
TEC current D2 [A]
TEC current D3 [A]
TEC current D4 [A]

PickoffLogXX.txt
Pump power D1 [W]
Pump power D1 [W]
Pump power D1 [W]
Pump power D1 [W]
Laser power D1 [W]
Laser power D2 [W]
Laser power D3 [W]

DiodeCurrentLogXX.txt
Diode current D1/2 [A]
Diode current D3/4 [A]

To access the files please log onto the system via FPT.

FTP-Server
The system runs an active FTP server for file-transfer to the root directory \Hard Disk\FTP\.
Username: user
Password: enhLIGO

System Time
The system time is set to PST

6.7 NPRO driver

The NPRO can be switched on or off by the control box. All other settings have to be made at the NPRO driver.These settings are :

- NPRO pump diode injection current
- NPRO crystal temperature
- Noise eater on/off
- NPRO pump diode temperature

At the time of shipping the pump diode current for 2 W output power is 2.3 A.
The NPRO can be switched on and off manually using the buttons at the driver. The control box detects this and will show a message that the NPRO has been switched on or off. At the time of
Further information about the NPRO can be found in the NPRO manual and the data sheet in the appendix.

6.8 Interlocks and safety shutdowns

This section describes the cases in which the system shuts itself down for safety reasons or in case of an error. Each time this happens the seed laser and the laser diodes are

shut down immediatly and a message appears at the screen. In order to be able to switch the system back on the Reset button has to be pushed after these events.

6.8.1 Safety shutdowns

The Control Box and the Diode Box have connectors for external interlocking (see Figure 4-3). In case these conections are open the system is shut down. Use these to connect the system to your laboratory security chain.

The MOPA head is equipped with a lid interlock in form of a microswitch. If this switch is opened by taking the lid off. the laser is shut down. This interlock can be defeated for alignment purposes with adhesive tape or a cable tie.
These Interlocks run independantly from the software.

6.8.2 Error Interlocks

The system shuts itself down in case one of the following errors occur:

Chiller error - system off
Is configurable at the neslab chiller. Is set to be triggered in case the water flow is too low or the chiller is switched off. Make sure the chiller is on and the water hoses are not bend or squeezed. Make sure the diagnostics cable is plugged in correctly.

Xtal temp > 30°C - system off
Is triggered if the crystal holder temperature exceeds 30° C. Make sure enough water flows through the amplifier head and the hoses are not bend or squeezed. Check if the amplfier diagnostics cable is plugged in correctly.

DB heatsink temp temp > 30°C - system off
Is triggered in case the DB heatsink temperature exceeds 30° C. Make sure enough water flows through the Diode Box and the hoses are not bend or squeezed.

Coupler communication error - system off
Check communication (Boxes switched on, ethernet communication, ...)

Laser Diode temp. error – s**ystem off**

Is triggered in case the laser diode temperature is out of range (15-35° C).
Contact the LZH.

Diode hardware temp guard alarm - system off

Is triggered by hardware switches in case the laser diode temperature exceeds 37° C. Contact the LZH.

Laser power watchdog error - system off

See Chapter 6.1 fior watchdog description

6.8.3 Warnings

Warnings do not shut down the laser system.

Chiller Warning

Is configurable at the chiller. Is set to trigger at low water niveau. Refill destilled water.

Shutterstate unclear

Make sure the MOPA head diagnostics cable is plugged in correctly.

7 Setting up the laser system

This laser system has to be unpacked and set up by trained personnel only in a clean environment.

The MOPA laser head is not sealed at the bottom. **Remove the plastic foil only in a clean environment** e. g. before setting it to its place on the optical table.

- Place the MOPA head at the desired position at the laser table.
- Unscrew the screws of the top lid and remove the lid.
- Use the 4 holes in the middle of the breadboard to screw it tightly to the optical table.
- Screw the 4 corners to the table.
- Carefully connect the fibers. Make sure the fiber ends are not contaminated.
- Connect the diagnostic cable and the cooling water tubes to the amplifier head.
- Connect the laser cable to the NPRO
- Connect the water distributors to the chiller and connect the water hoses of the laser head and diode box. Make sure you hear a distinct click each time you connect the water plugs to ensure they snap in correctly.
- Fill the water chiller with destilled water until the water level is between min. and max. marks. If long water tubes are used refilling might be needed when the water fills the tubes.
- Connect the CB and DB cables as shown in chapter 5.2.

Remove the BNC shortening plugs at the current modulation connection before starting the amplifier!

It is possible that the system will be misaligned due to transportation! Before switching the system on do the alignment procedures as described in chapter 8.

8 Alignment

Misalignment of the MOPA system will be probably due to deformation of the base plate or transportation. Alignment can be done by the following procedures without opening the amplifier head. In case of a misalignment of the amplifier head contact the LZH.

8.1 Alignment of the MOPA head

- Make sure the system is switched off
- Open the lid of the MOPA head
- Defeat the lid interlock with adhesive tape or a cable tie
- Place a beam dump between mirrors M4 and M5
- Reduce output power for alignment
    - Enable manual Mode in the MOPA control interface.
    - Shut the shutter of the Mephisto 2000 and switch it on.
    - Set the injection current at the Mephisto driver to a low value, e. g. 1.2 A to reduce output power.
- Open the pinholes between lenses L4 and L5 completely
- Open the shutter and check if the beam passes properly the EOM and the AOM without being cut.
- Reduce the laser power behind the faraday isolator to a few milliwatt by turning the half-wave plate in front of it and thereby sending most of the power into the beam dump. Increase the injection current of the Mephisto slowly until it reaches the nominal value (2.3 A) in order to have the proper beam caustic for the mode matching and check in parallel the power behind the isolator.
- Activate the AOM and check if the 0. and 1. order are transmitted through the Faraday isolator. The 1. order should be absorbed in the beam dump behind the isolator.
- Check if the laser beam passes the two pinholes between L4 and L5 properly.
- If the beam does not pass the pinholes properly use mirrors M2 and M3 respectively for aligning. Use M2 to get the beam through the pinhole next to L4 and M3 to get it through the other pinhole respectively. The lens L3 should not be of interest.

- Make sure the laser hits the photodiode behind the second mirror in front of the amplifier head. Slight adjustments can be done with the lens L6 in front of the photodiode.
- Proceed with chapter 8.2

8.2 Alignment of the Electro-Optic Modulator (EOM / Pockels Cell)

- Block the beam at the input of the amplifier to prevent it from damage during the adjustment procedure.
- There are four adjustment screws in the EOM base. Each pair controls the horizontal and vertical displacement of one end of the EOM. Adjust each screw to center the beam to the input and output aperture of the EOM by eye.
- Check the amount of power in front of and behind the EOM with a power meter. The loss inside the EOM should be negligible.
- Put the power meter behind the point of the pick-off for the diagnostic photodetector to monitor the NPRO power during the adjustment procedure. The detector head can also be used as a beam block.
- Connect a cw source (sine, e.g. function generator or network analyzer) with a large amplitude (max. RF power: 10 W) to the input of the broadband EOM. The frequency should be 10MHz to 100MHz and depends on the maximum bandwidth of the photodetector. The operating frequency is 35.5MHz but the adjustment can be done with any frequency where the laser is shot noise limited to a level of a few mW (>10MHz).

(Bandbreite Photodetektor bisher unbekannt, genaueres später)

- Connect the DC-output of the photodetector with a spectrum analyzer. Change the mid frequency to the frequency of the source and the span to a few 100kHz.
- Adjust the input sensitivity to the maximum. You should now see a residual amplitude modulation of the EOM at the modulation frequency.
- Use the adjustment screws of the EOM base to minimize the residual amplitude modulation. Repeat this process for all four screws, until you have minimized it.

- Make sure you don't steer the EOM such that the incident light no longer goes through the aperture ! Check this by watching the power on the power meter!
- Iterate through this process one or two more times, until you no longer need to make changes.
- Replace the photodetector with a beam scanner and check the shape of the output. Maximum transmission and minimum amplitude modulation does not always mean best beam quality. Sometimes there can be strange artifacts or distortions. If there are, make small adjustments to the screws to restore good beam quality.
- The EOM is now aligned.

8.3 Alignment of the Acousto-Optic Modulator (AOM)

- Block the beam at the input of the amplifier to prevent it from damage during the adjustment procedure.
- There are four adjustment screws in the AOM base. Each pair controls the horizontal and vertical displacement of one end of the AOM. Adjust each screw to center the beam to the input and output aperture of the AOM by eye.
- Check the amount of power in front of and behind the AOM with a power meter. The loss inside the AOM should be negligible.
- Put the power meter behind the point of the pick-off for the diagnostic photodetector to monitor the NPRO power during the adjustment procedure. The detector head can also be used as a beam block.
- Connect an AOM-driver (80MHz, up to 2W) to the input of the AOM. Operate the driver in cw-mode with maximum output power.
- Use the adjustment screws of the AOM base optimize the diffraction efficiency. The diffracted beam must hit the beam block in front of the isolator !.
- Connect the DC-output of the photodetector with a network analyzer. Change the setup to a bode plot with a frequency span from 1kHz to 1MHz.
- Now operate the AOM-driver with a large dc-output power and an amplitude modulation to measure the small signal transfer function of the AOM.
- Adjust the input sensitivity and you should now see the amplitude transfer function of the AOM.

- Use the horizontal adjustment screws of the AOM base to minimize the phase lag without reducing the diffraction efficiency. Repeat this process for both screws until you have minimized it (to about 45° at 500kHz) ???
- Replace the photodetector with a beam scanner and check the shape of the output. Maximum transmission and maximum amplitude modulation does not always mean best beam quality. Sometimes there can be strange artifacts or distortions. If there are, make small adjustments to the screws to restore good beam quality.
- Iterate through this process one or two more times, until you no longer need to make changes.
- The AOM is now aligned.

8.4 Alignment for the amplifier head

- Make sure the diodes are switched off unless otherwise noted.
- Make sure the beam is attenuated to a few milliwatt by the half-wave plate in front of the isolator unless otherwise noted.
- Check if the laser beam is transmitted through the amplifier head. The beam gets clipped at the amplifier crystal holders due to the lack of the thermal lenses otherwise induced by the pump light. For alignment purposes this is normal.
- Use only the mirrors M4 and M5 (see Figure 4-2) in front of the amplifier to adjust the incident beam. An IR detector card at the output can be used as a help for adjustment.
- When you can not increase the brightness of the beam on your detector card by aligning mirrors M4 and M5 place a power meter like the LM 10 from Coherent in front of the MOPA shutter and slowly increase the incident power slightly by rotating the half-wave plate until you have a proper signal on your power meter. The detected power should be in the range of 500 mW.
- Adjust for transmitted power until the amplifier transmits roughly 70% of the incident beam.
- Increase the laser power by turning the half waveplate in front of the faraday isolator back to maximum transmission though the isolator.
- Check again the transmitted power.
- Set the pump diode current to 30 A and switch the diodes on in the manual mode.
- Adjust for amplified power until an output power of about 12-14 W is achieved.
- Set the pump diode current to nominal value (48 A) and adjust for output power.

9 Using the laser system

9.1 Laser output characteristics

At the nominal working point the MOPA system emits 35 W at 1064 nm. The beam radius at the output window is **0.2 mm** with a divergence angle of **1.7 mrad**.
The laser is polarized vertically to the table.
For maximum pump power (above the nominal working point) the output power can be increased to the range of 50 W with degraded beam quality. The system is optimized to the working point and therefore the use at higher power levels is **not** recommended.
Due to scattering there is some highly divergent residual pump light at output window of the MOPA system of less than 30 mW at 808 nm. With the Master Oscillator deactivated or blocked and the amplifier pumped at nominal power the output ASE (Amplified Stimulated Emission) at 1064 nm is typically < 1 mW.

The remotely controllable shutter can be used to block the seed laser beam and therefore shut down the 35 W laser beam without shutting down the amplifier pump.
In case the ASE and the pump light also need to be blocked use the manual shutter at the housing.
Attention : Do not use the manual shutter to block the 35 W beam.
Doing this might contaminate the output window by igniting a plasma on the shutter due to the high intensity.

10 List of illustrations

11 Appendix

1. Electronic circut
2. Mephisto 2000 NE LIGO Manual
3. Mephisto 2000 NE LIGO Data sheet and test report
4. Mephisto 2000 NE LIGO connection diagram
5. Calibration certificate OPHIR NOVA II laser power meter
6. Calibration certificate OPHIR FL300A-SH laser power sensor head
7. EOM Manual
8. AOM data sheet
9. Faraday isolator data sheet
10. Faraday isolator manual
11. Pump data sheet
12. Pump diode handling manual
13. Amplifier crystal data sheet
14. Chiller Manual

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Company / customer	
Project description	Enhanced LIGO Reference System
Drawing number	
Commission	
Manufacturer (company)	Laser Zentrum Hannover e.V.
Path	
Project name	enhLIGO refSys
Make	
Type	
Place of installation	
Responsible for project	CV
Part feature	

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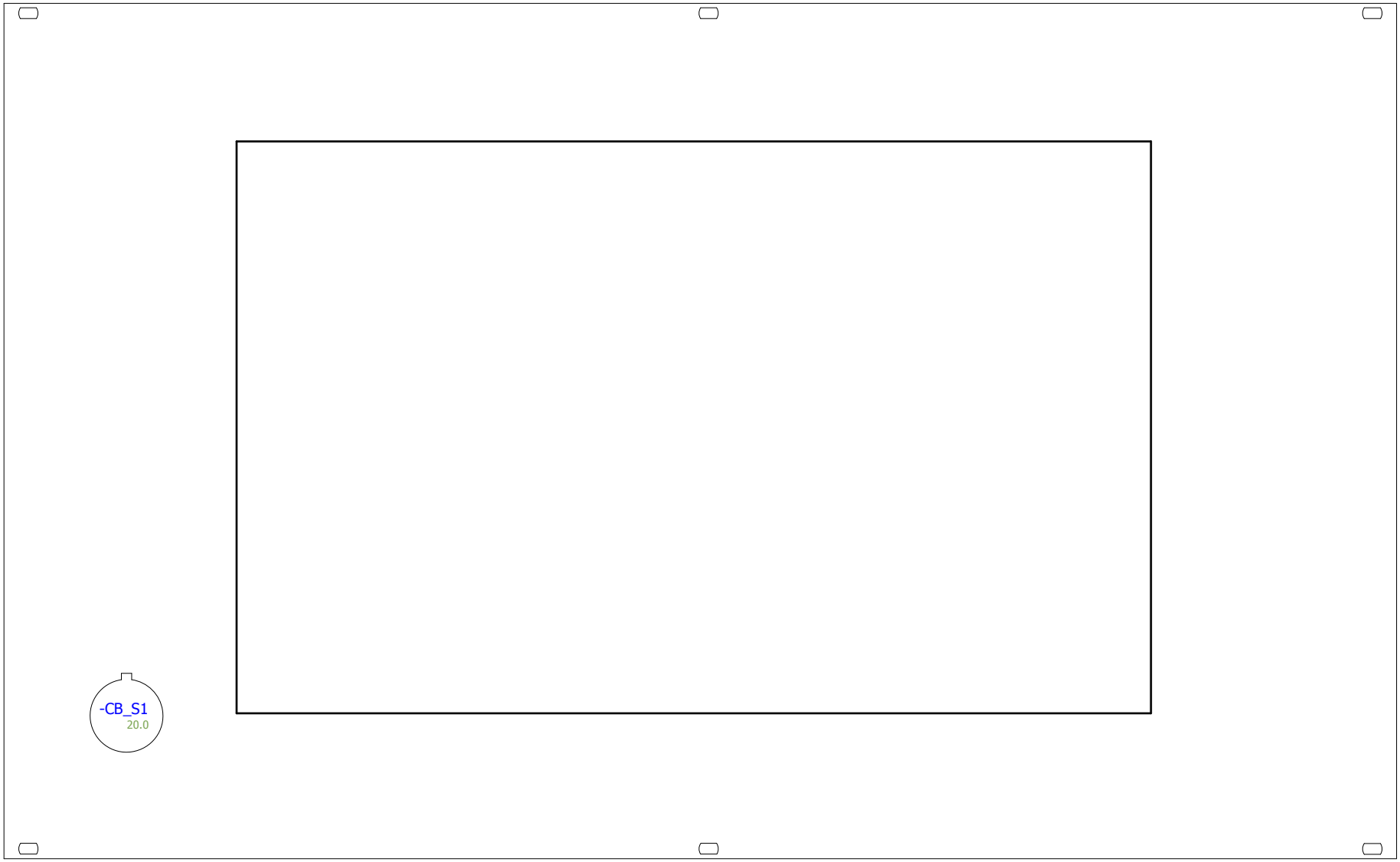

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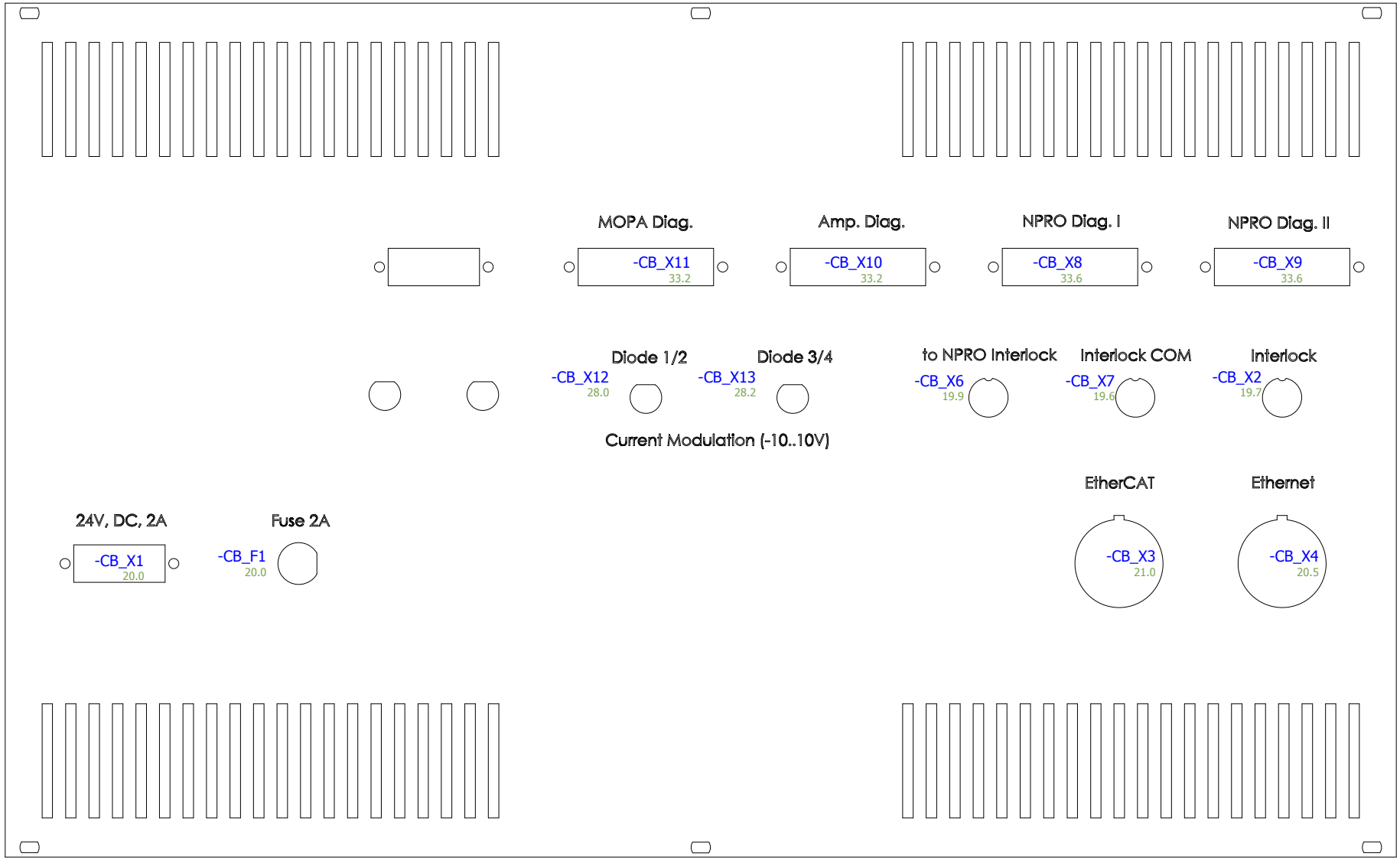

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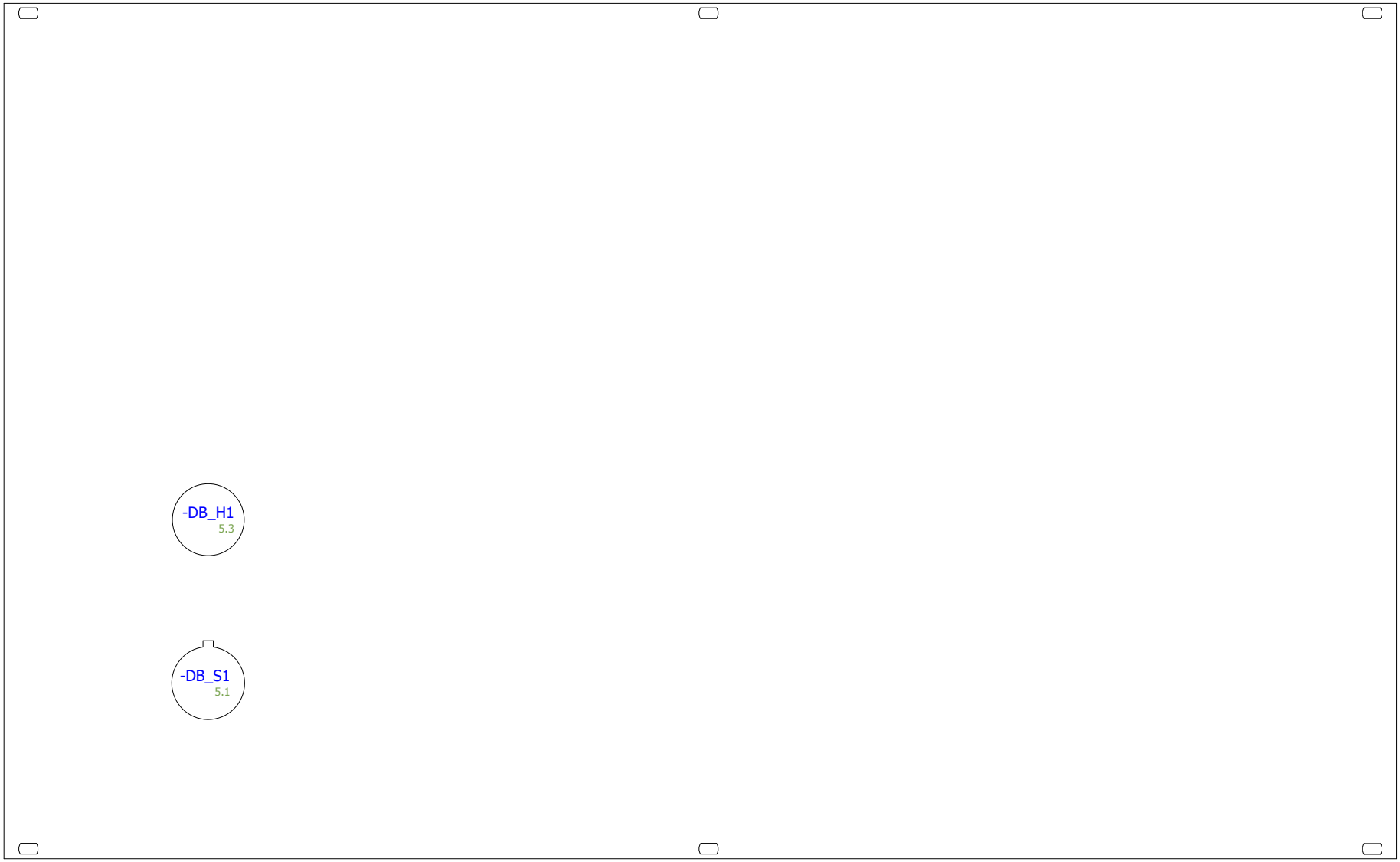

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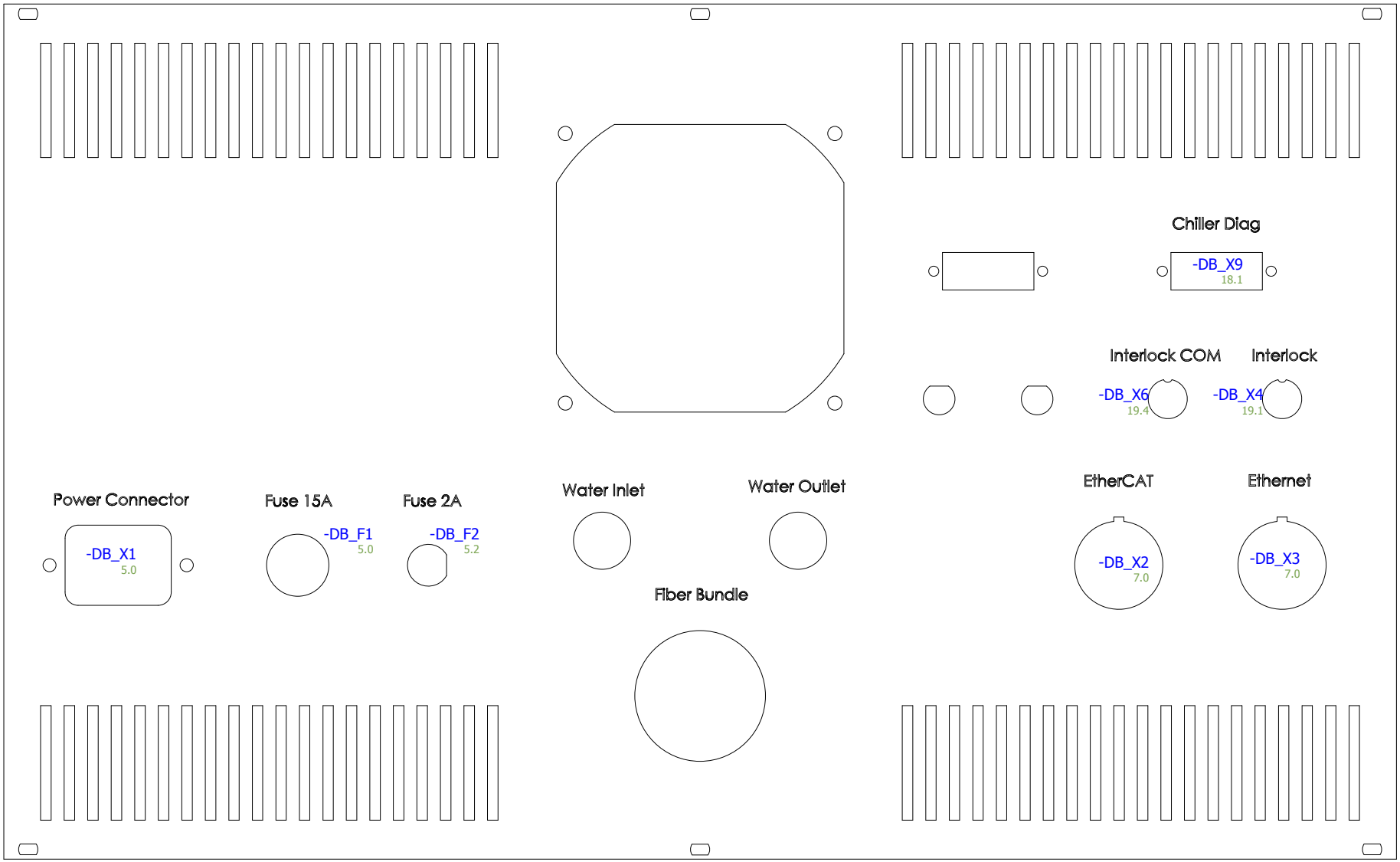

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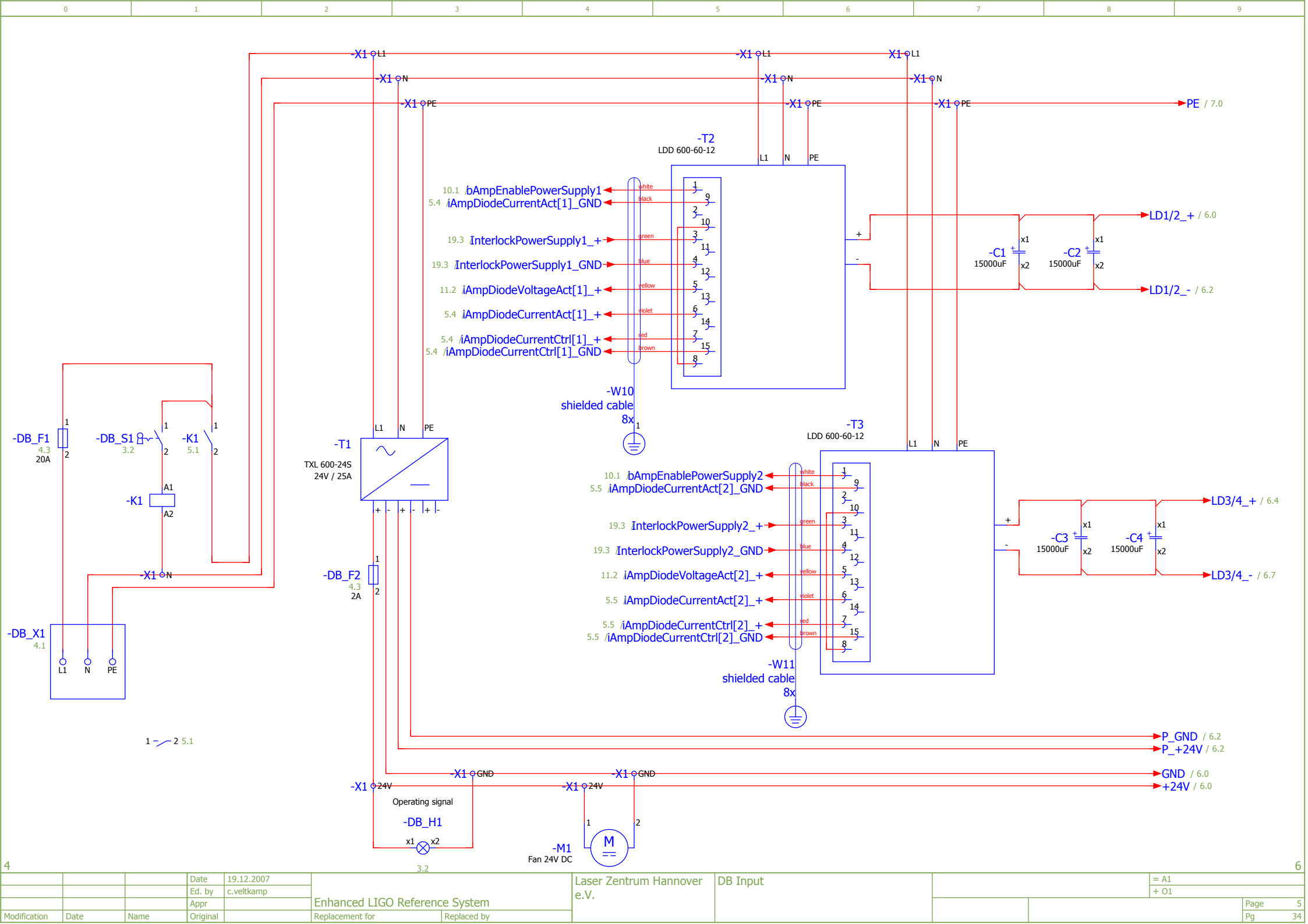
									Pg 34

Laser Zentrum Hannover e.V.

Backpanel DB



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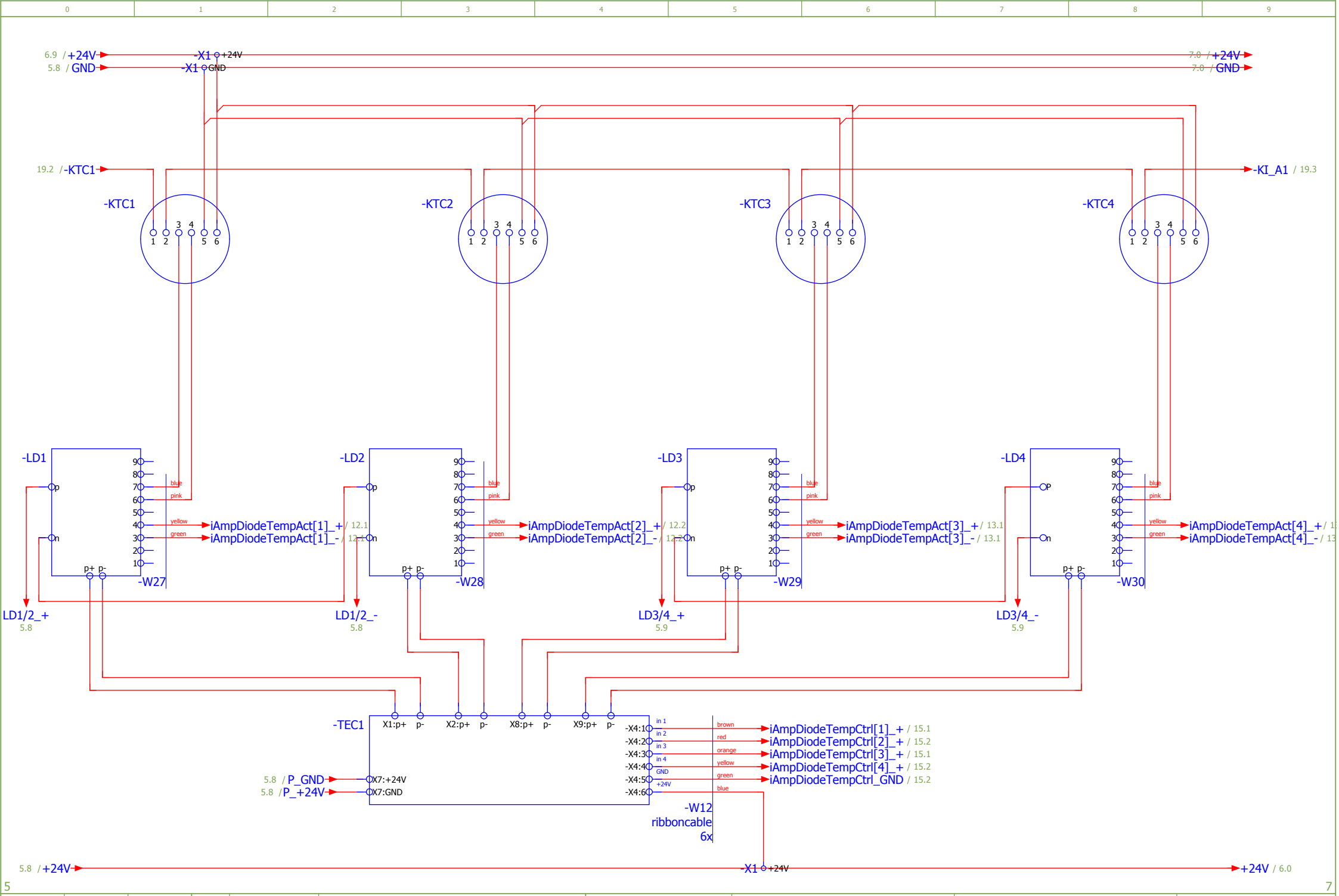

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Modification	Date	Name	Original		Replacement for	Replaced by			Page 6
									Pg 34

Laser Zentrum Hannover e.V.

DB Laserdiode

6.9 / +24V
6.9 / GND
-X1 +24V
-X1 GND
-X1 +24V
-X1 GND
+24V / 18.0
GND / 10.0

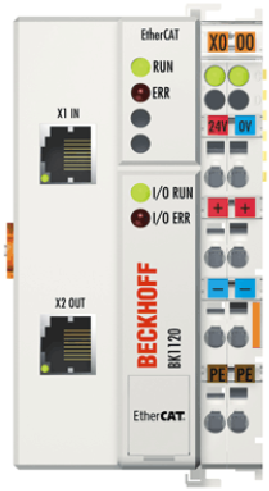
BK2
X1 IN
X2 OUT
BECKHOFF
BK1120
RUN
ERR
KL2.1
A C
B D
24V: -0V:
-+: -+:
-0-: -0-:
-PE: -PE:

-W22
21.1
RJ45 CAT.5E

-W26
RJ45 CAT.5E

-DB_X3
4.8
-DB_X2
4.7

21.0 / EtherCAT_DB



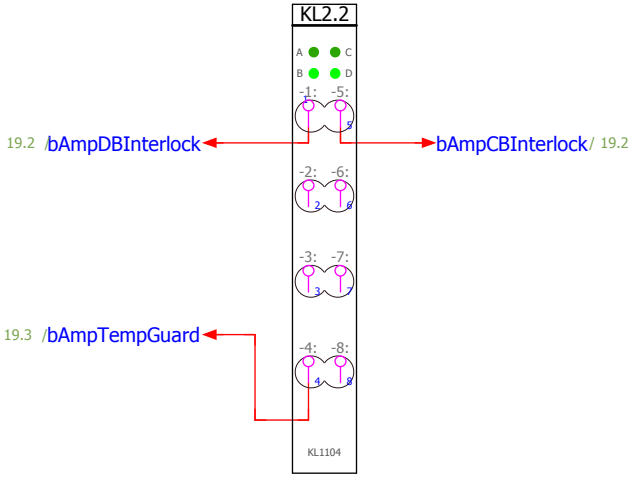
BK2
X1 IN
X2 OUT
BECKHOFF
BK1120
RUN
ERR

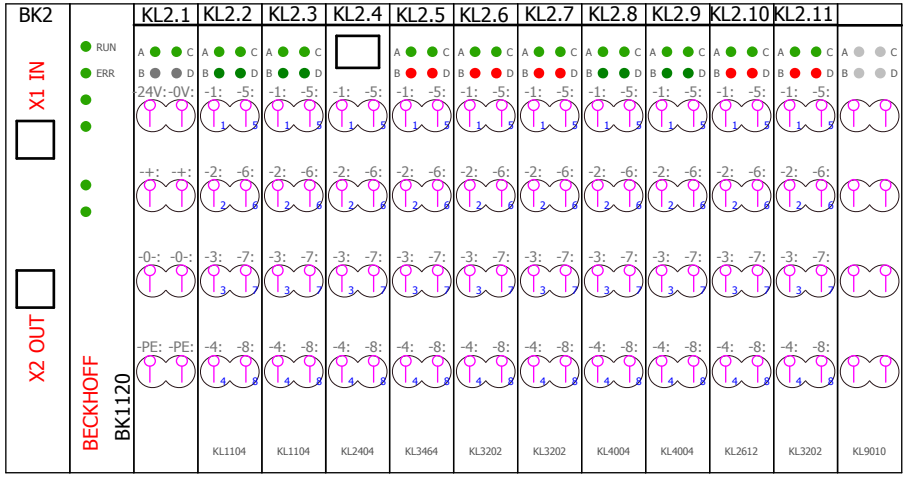
KL2.1	KL2.2	KL2.3	KL2.4	KL2.5	KL2.6	KL2.7	KL2.8	KL2.9	KL2.10	KL2.11	
	KL1104	KL1104	KL2404	KL3464	KL3202	KL3202	KL4004	KL4004	KL2612	KL3202	KL9010

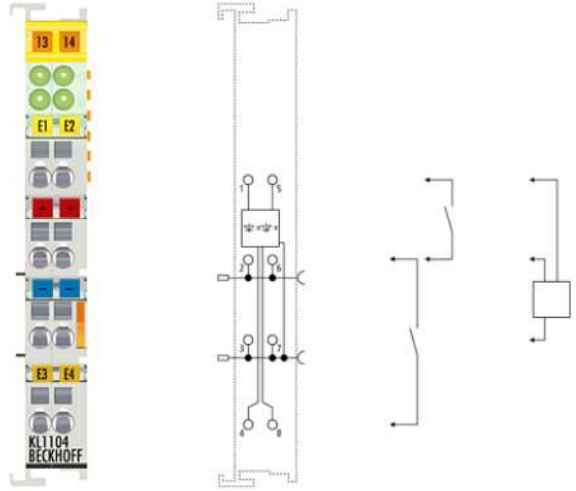
5.9 / PE
-X1 PE
PE / 21.0

6

8







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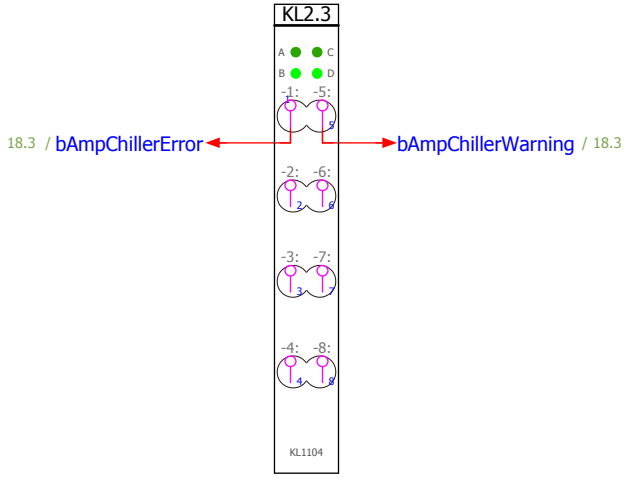

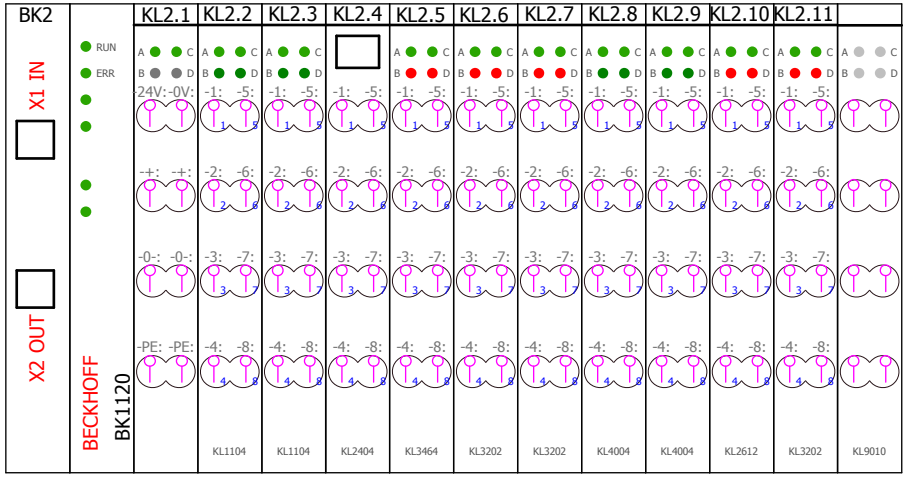

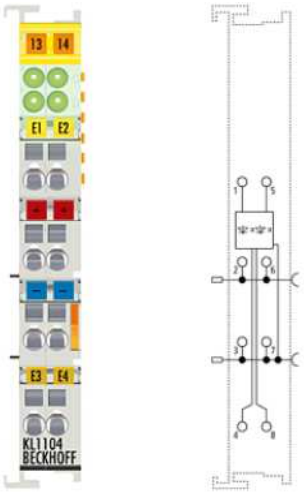

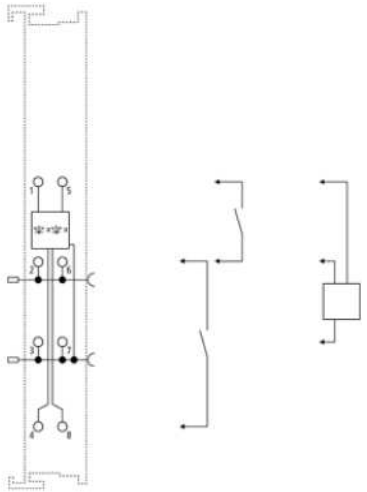

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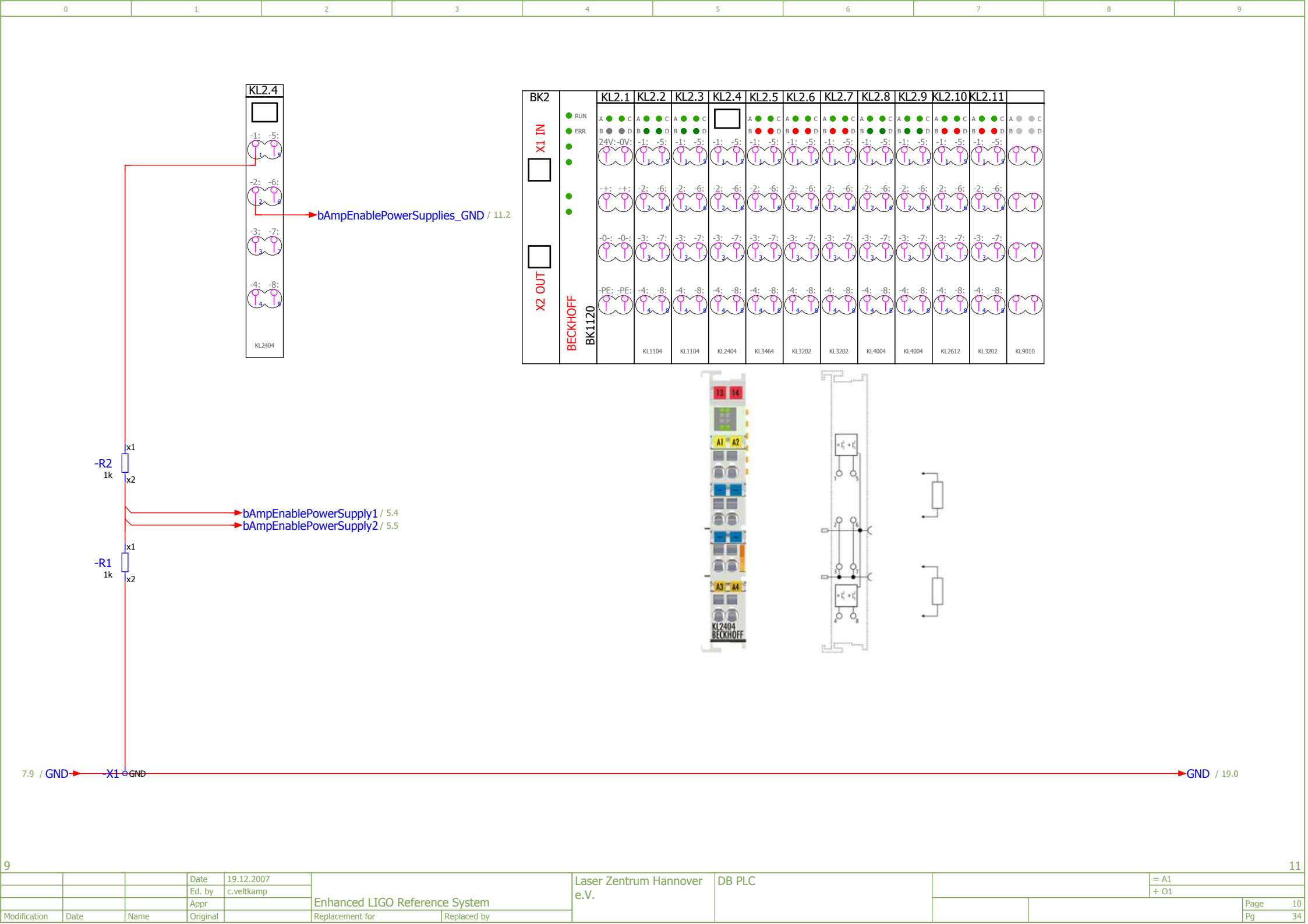
									Pg 34



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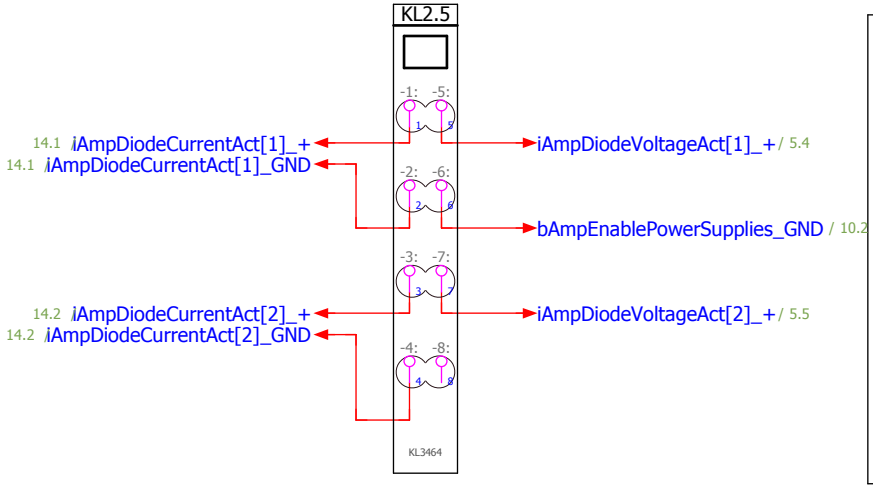

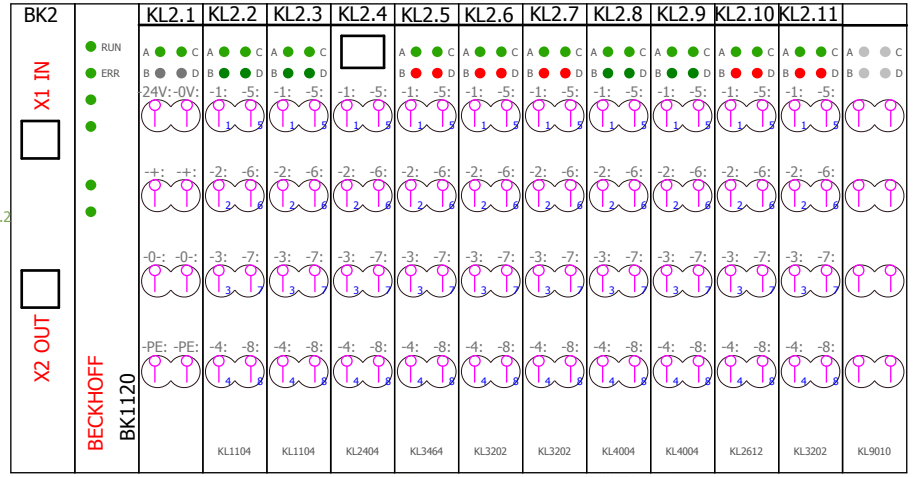

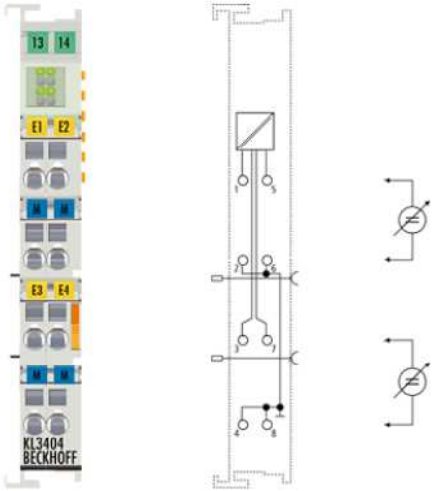

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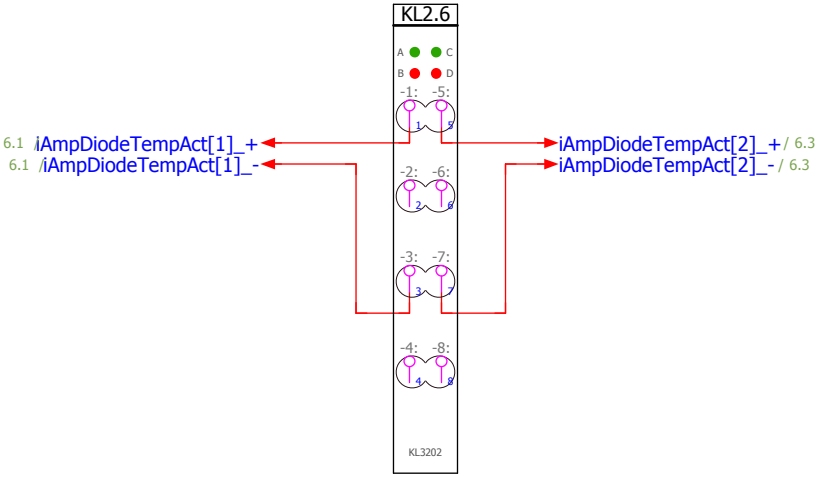

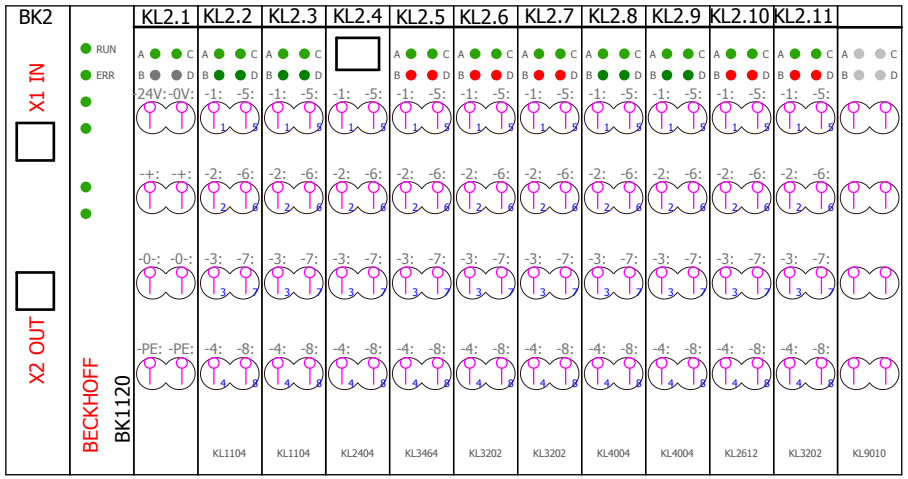

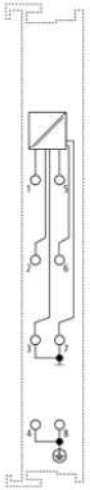

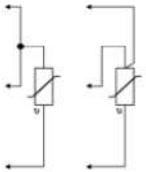

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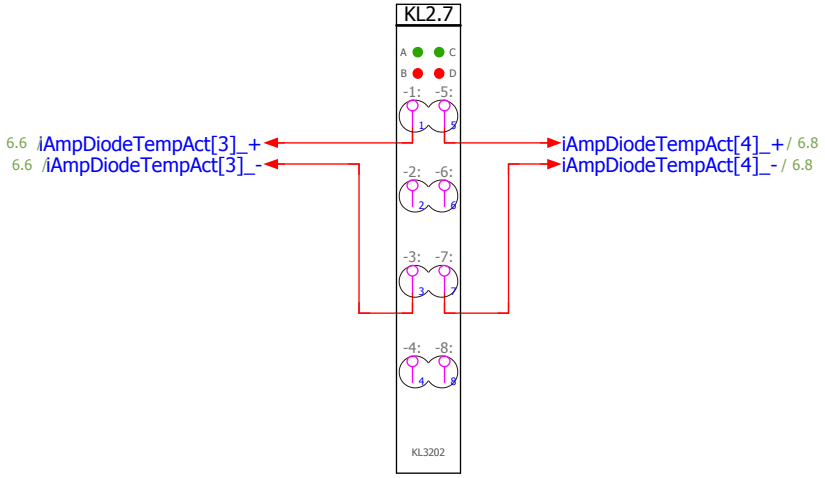

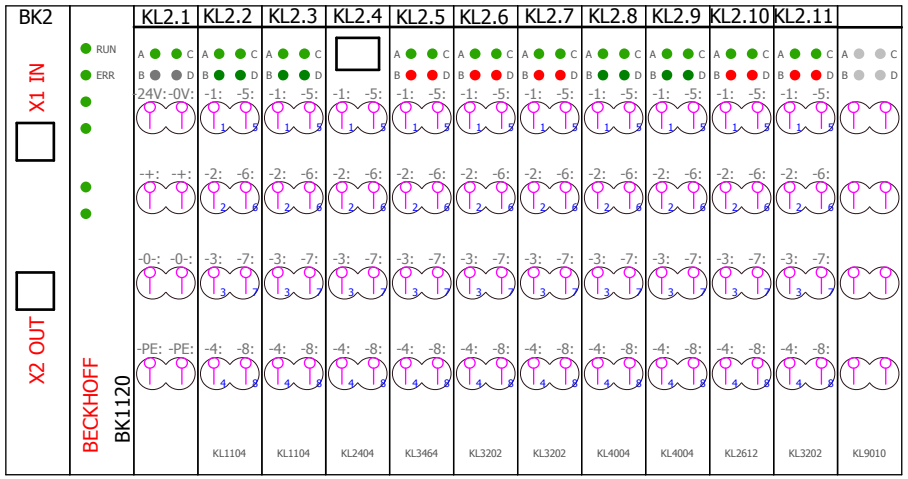

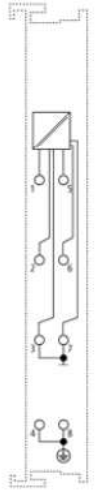

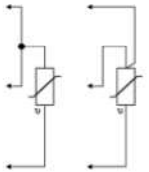

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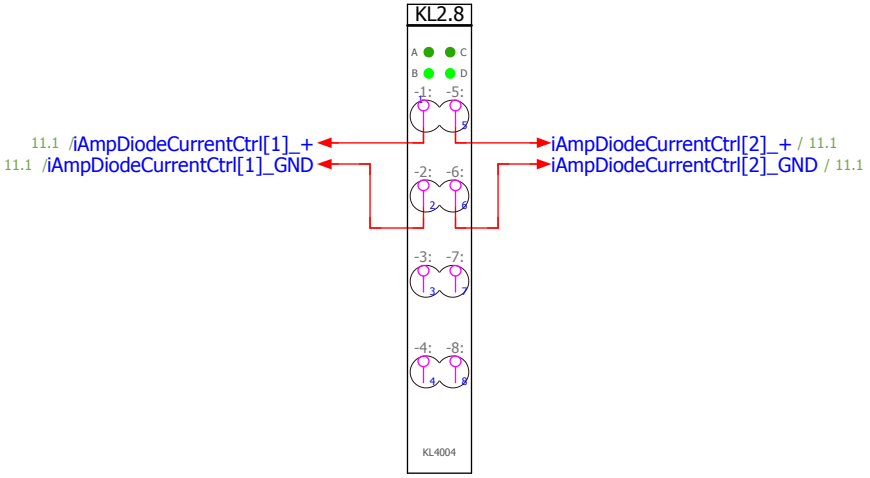

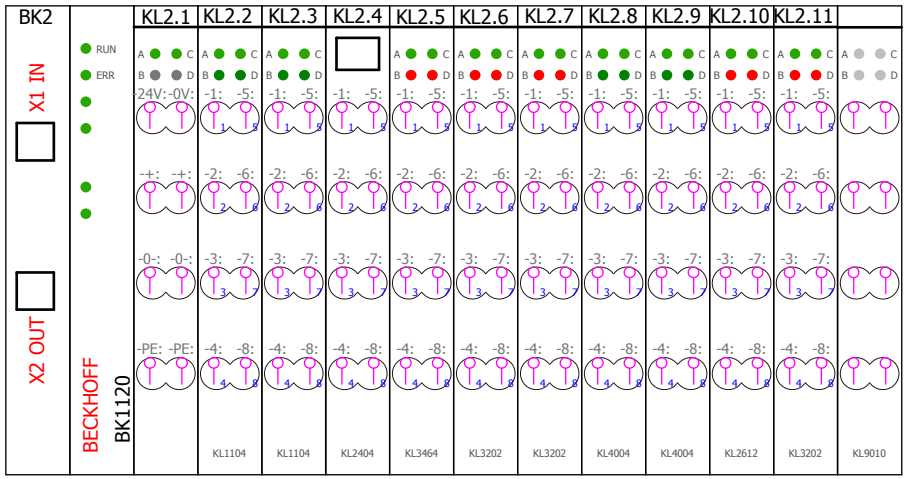

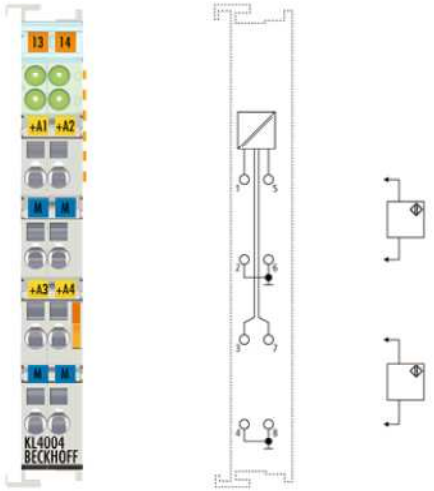

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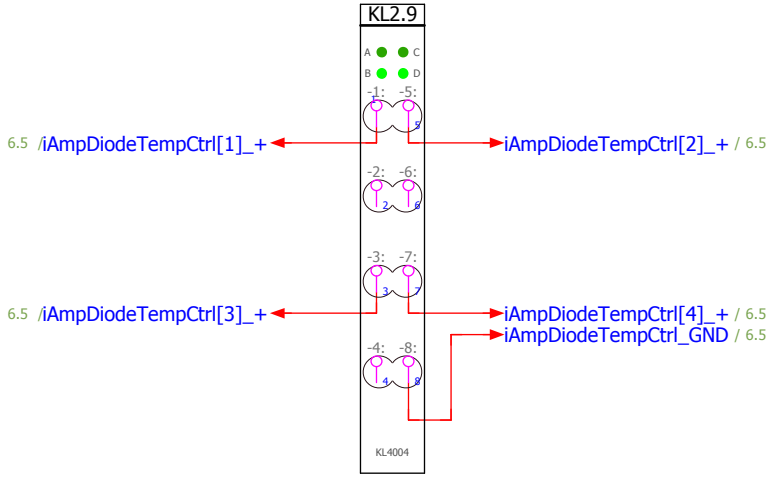

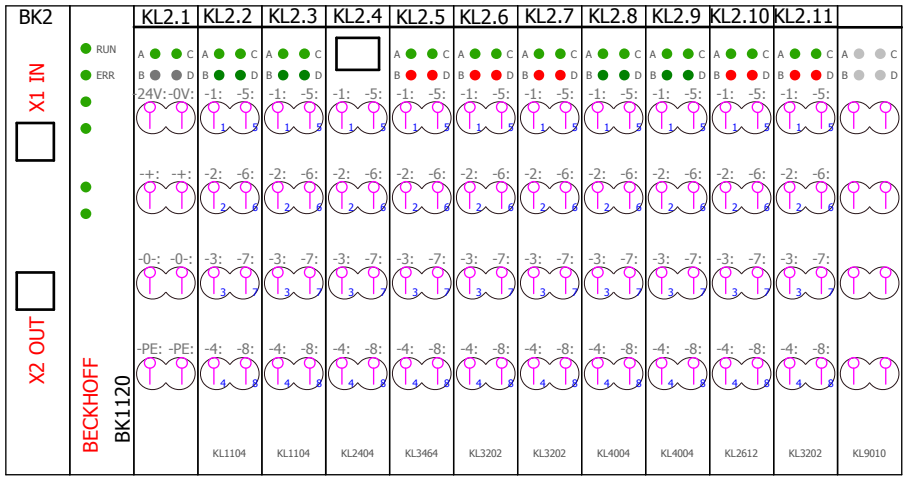

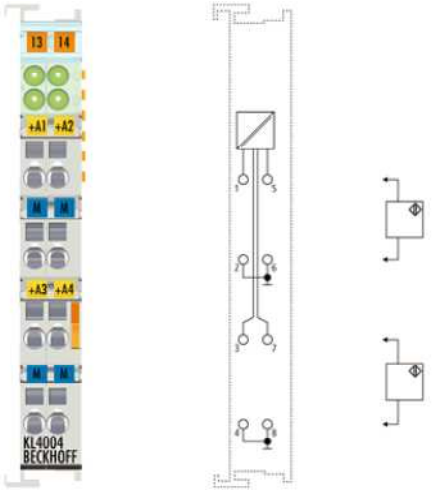

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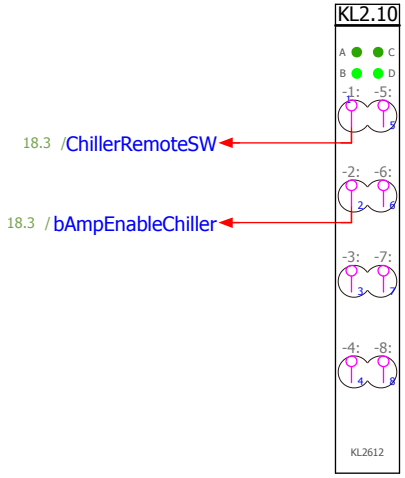

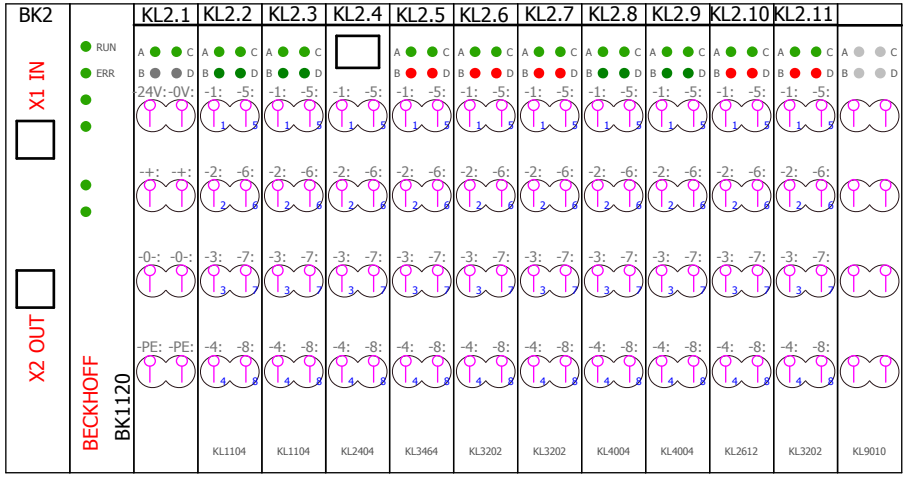

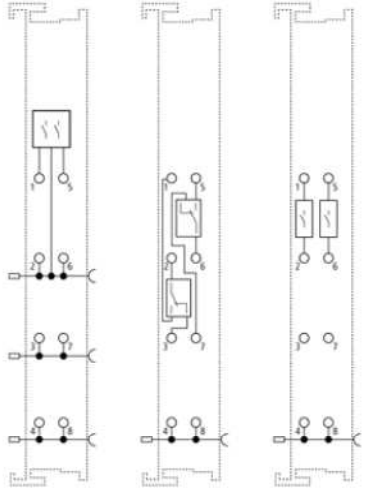

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17

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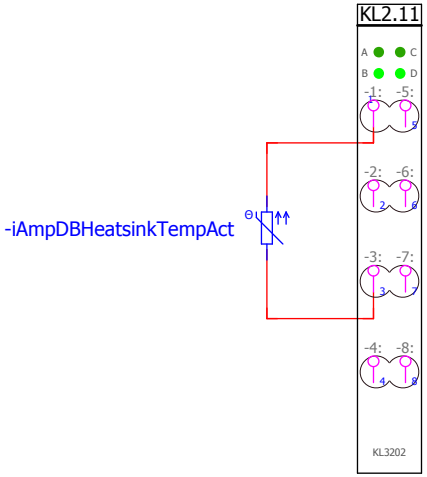

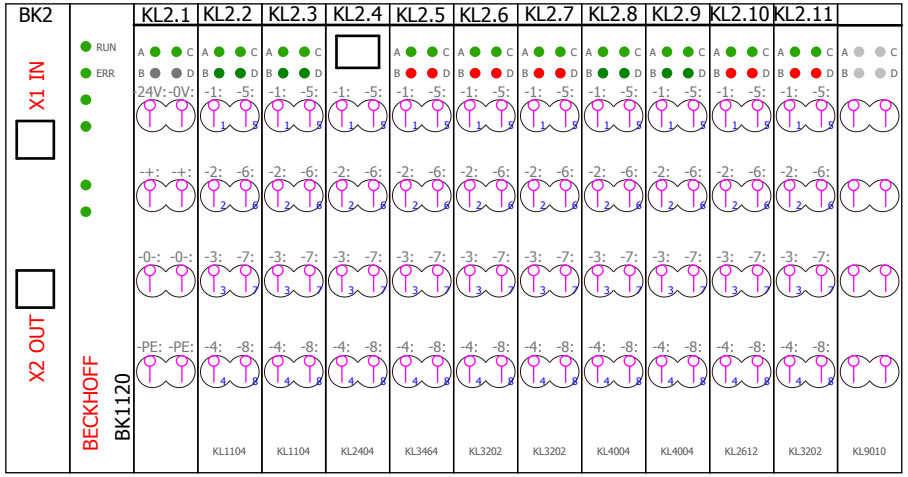

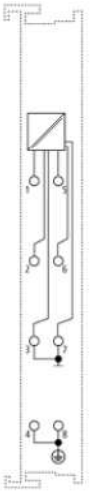

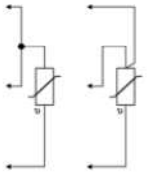

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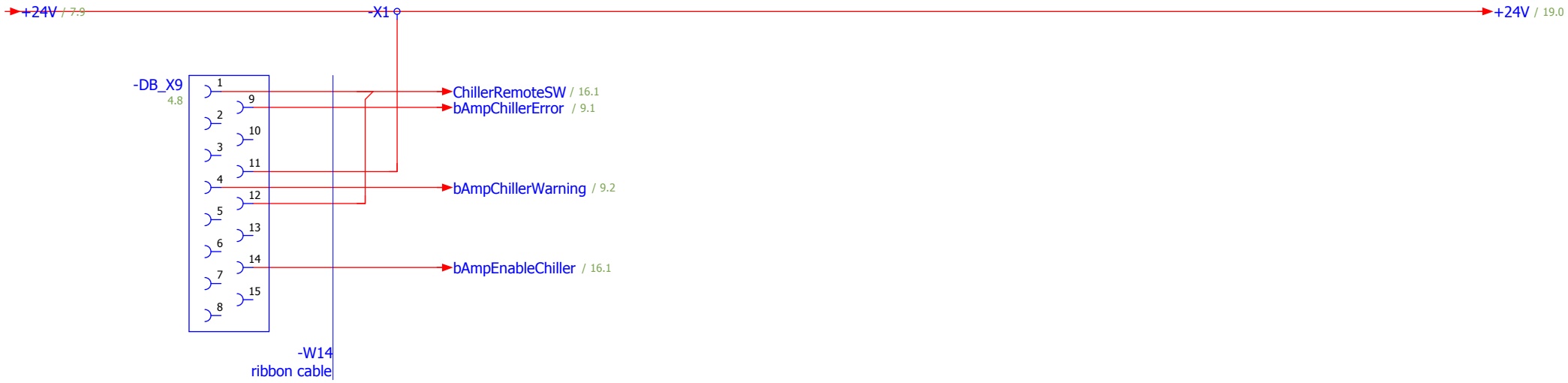

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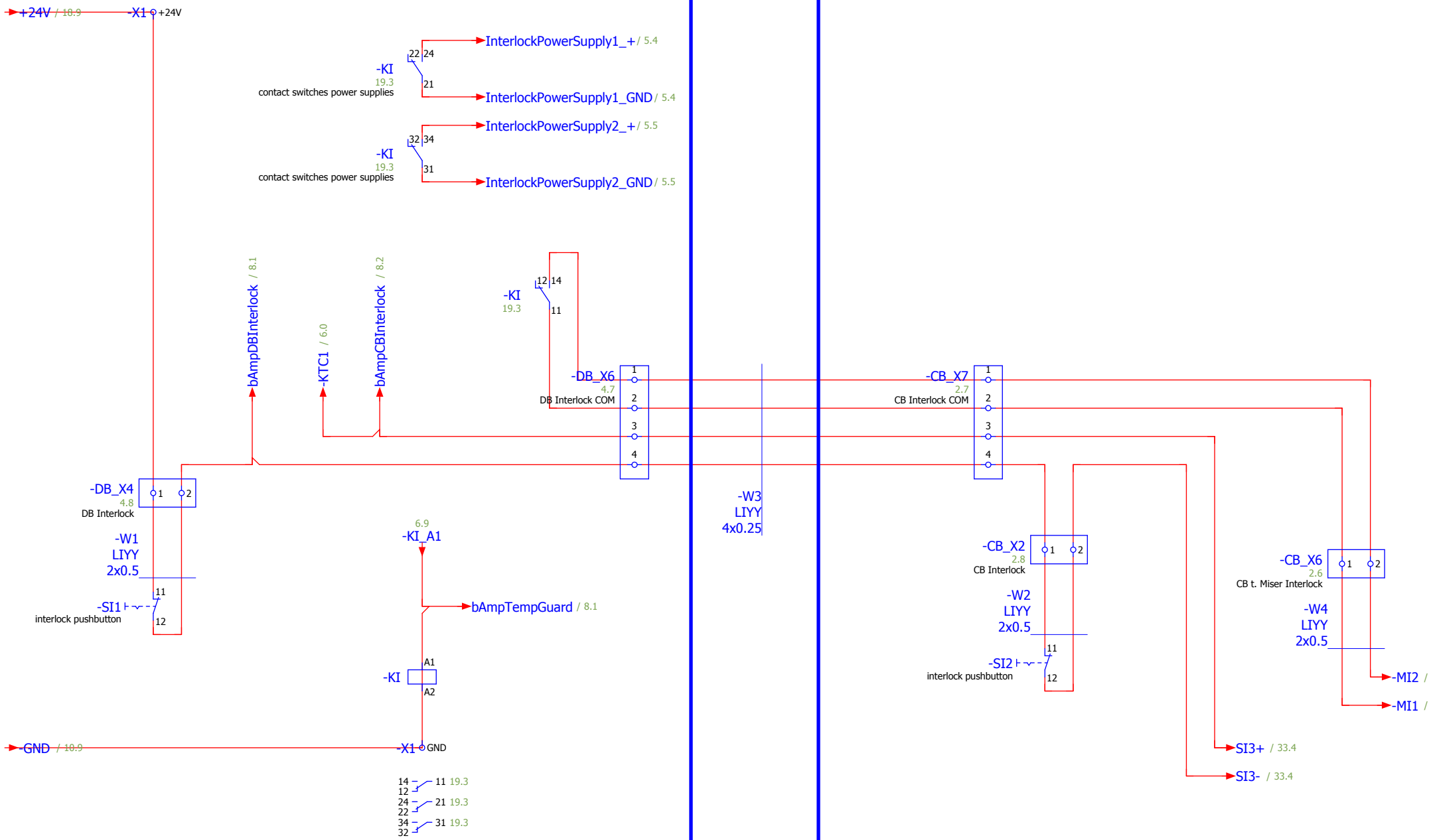

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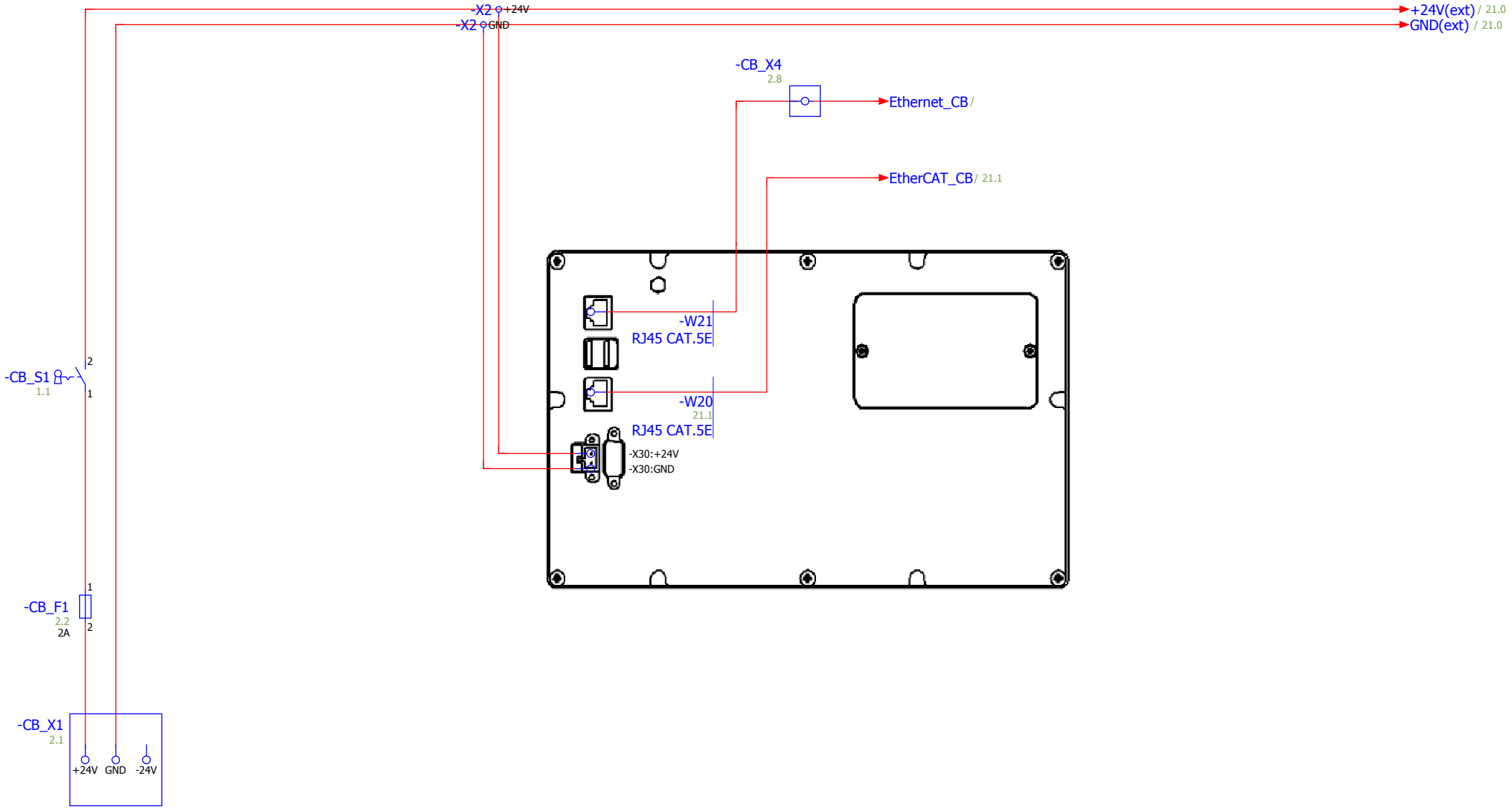
								Pg 34

Laser Zentrum Hannover e.V.

DB/CB Interlock



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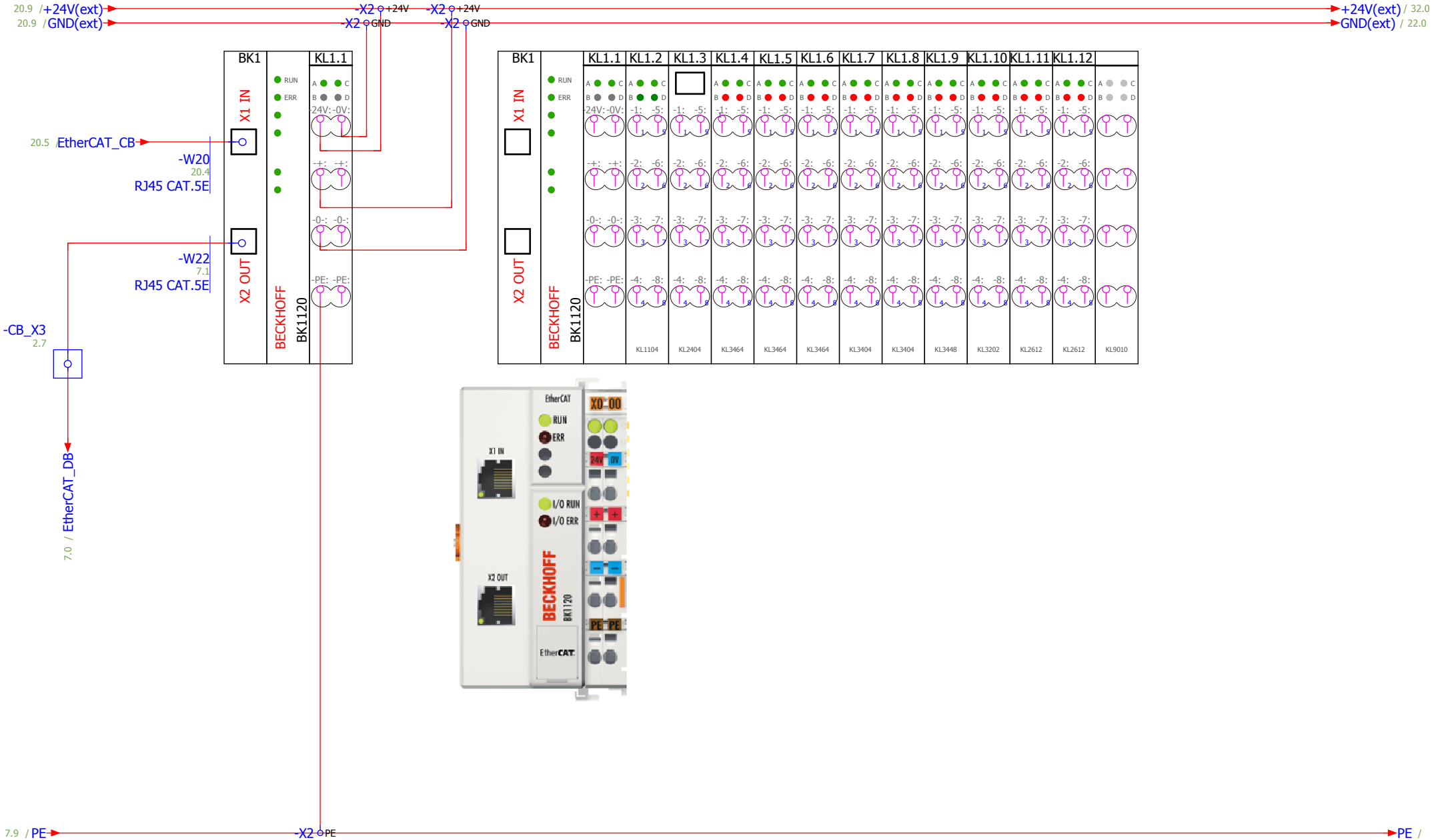

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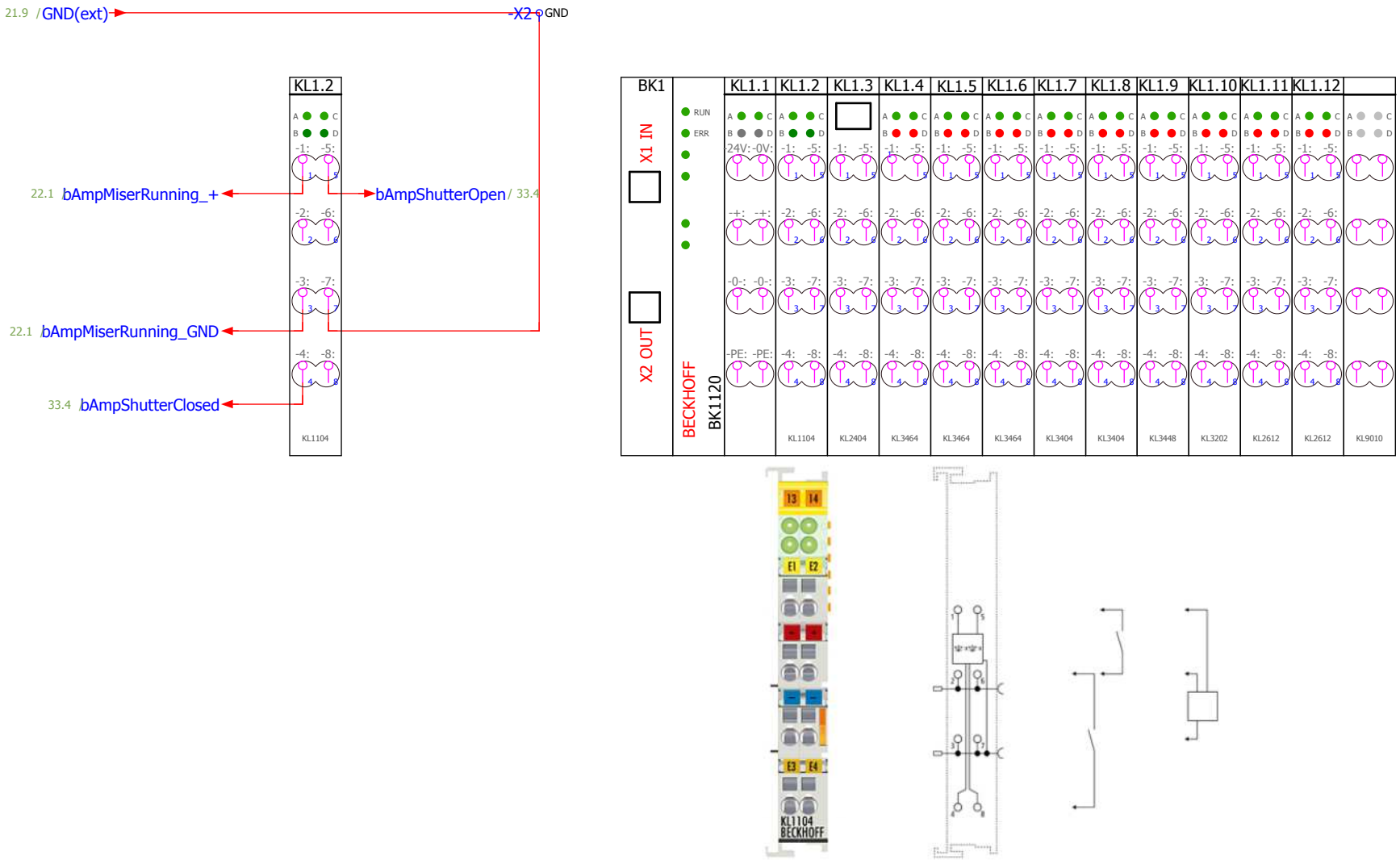

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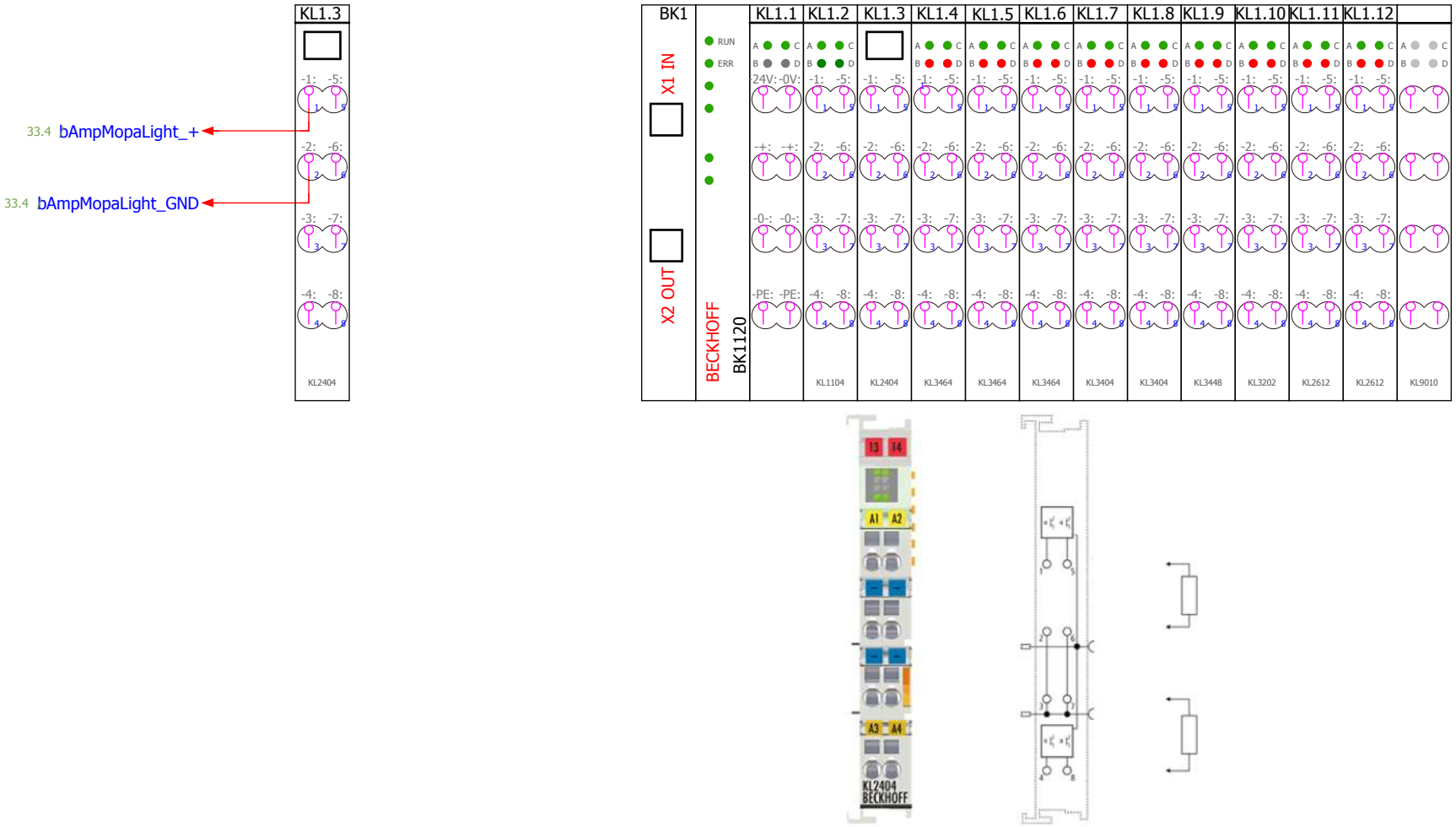

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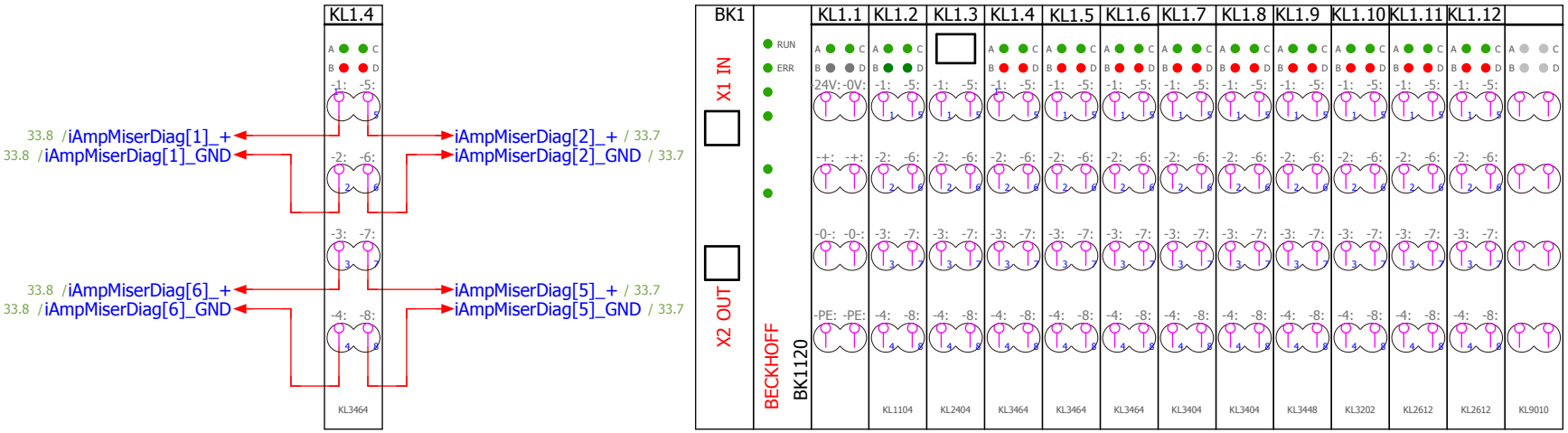

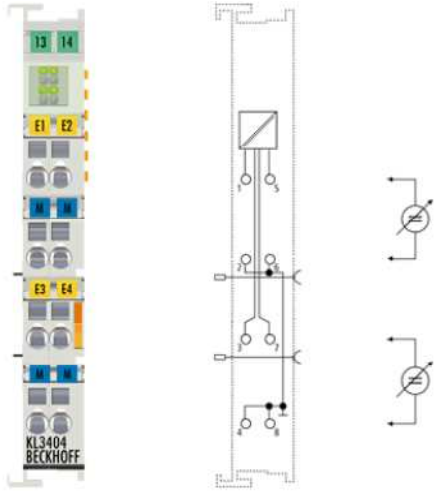

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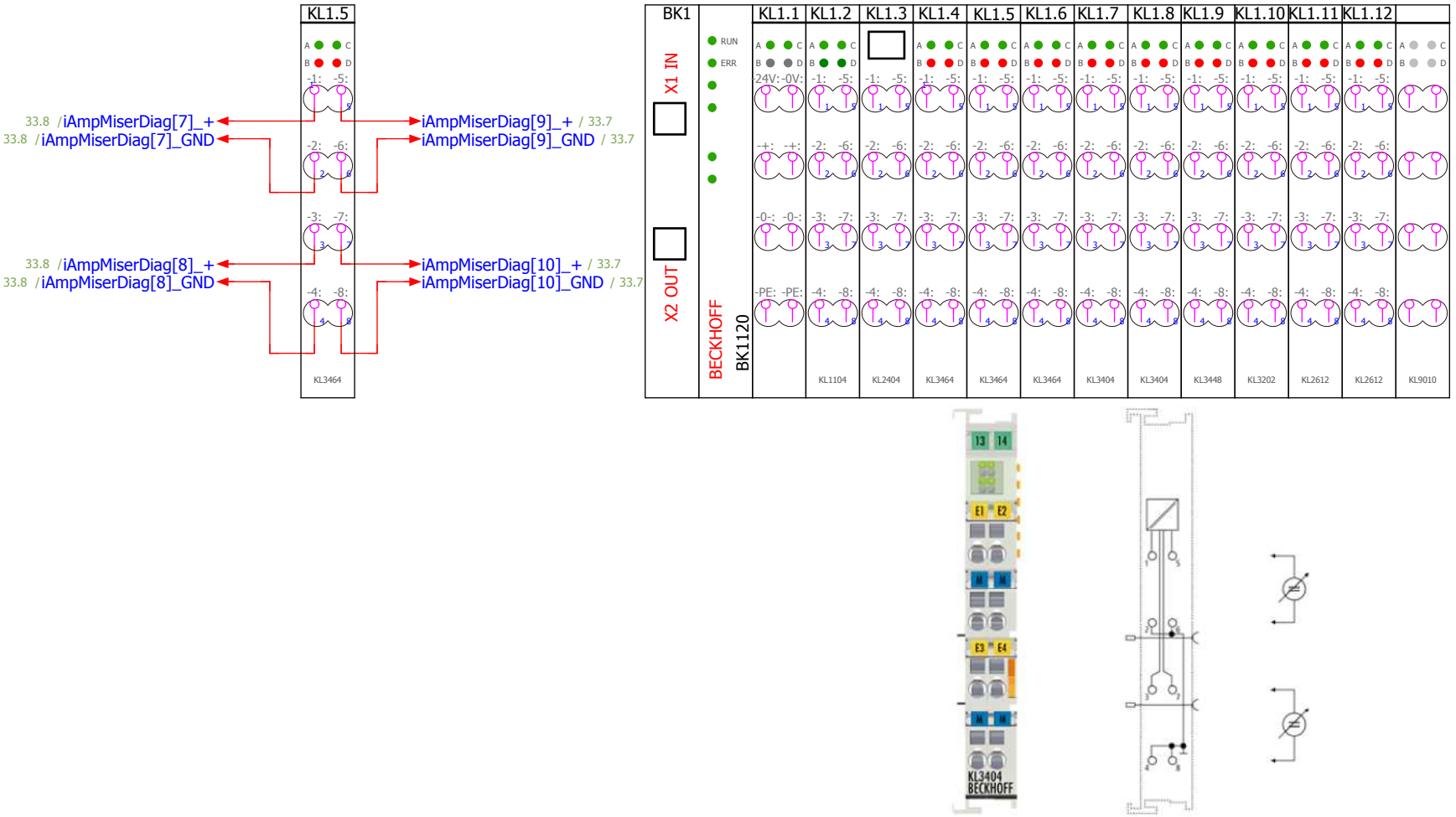

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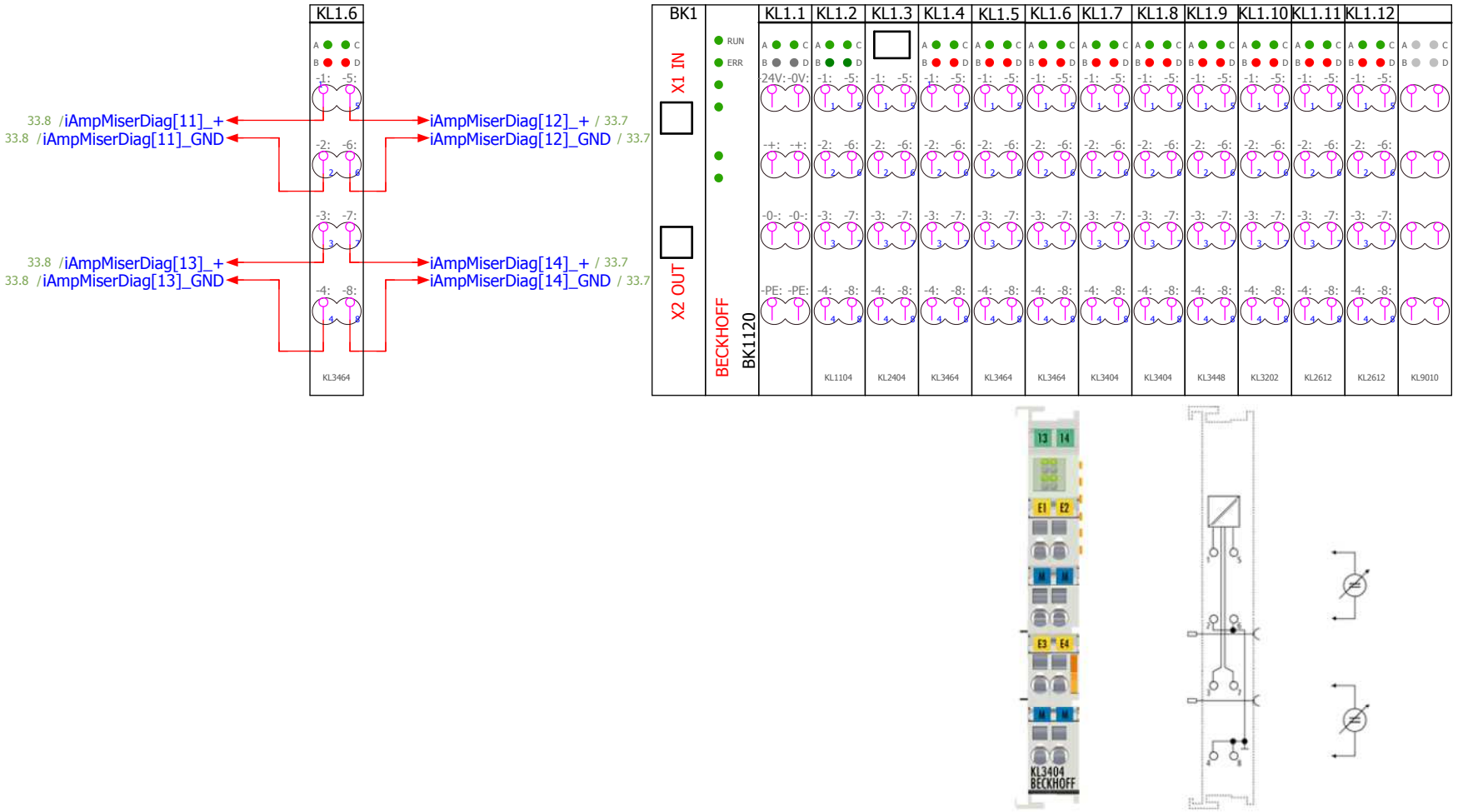

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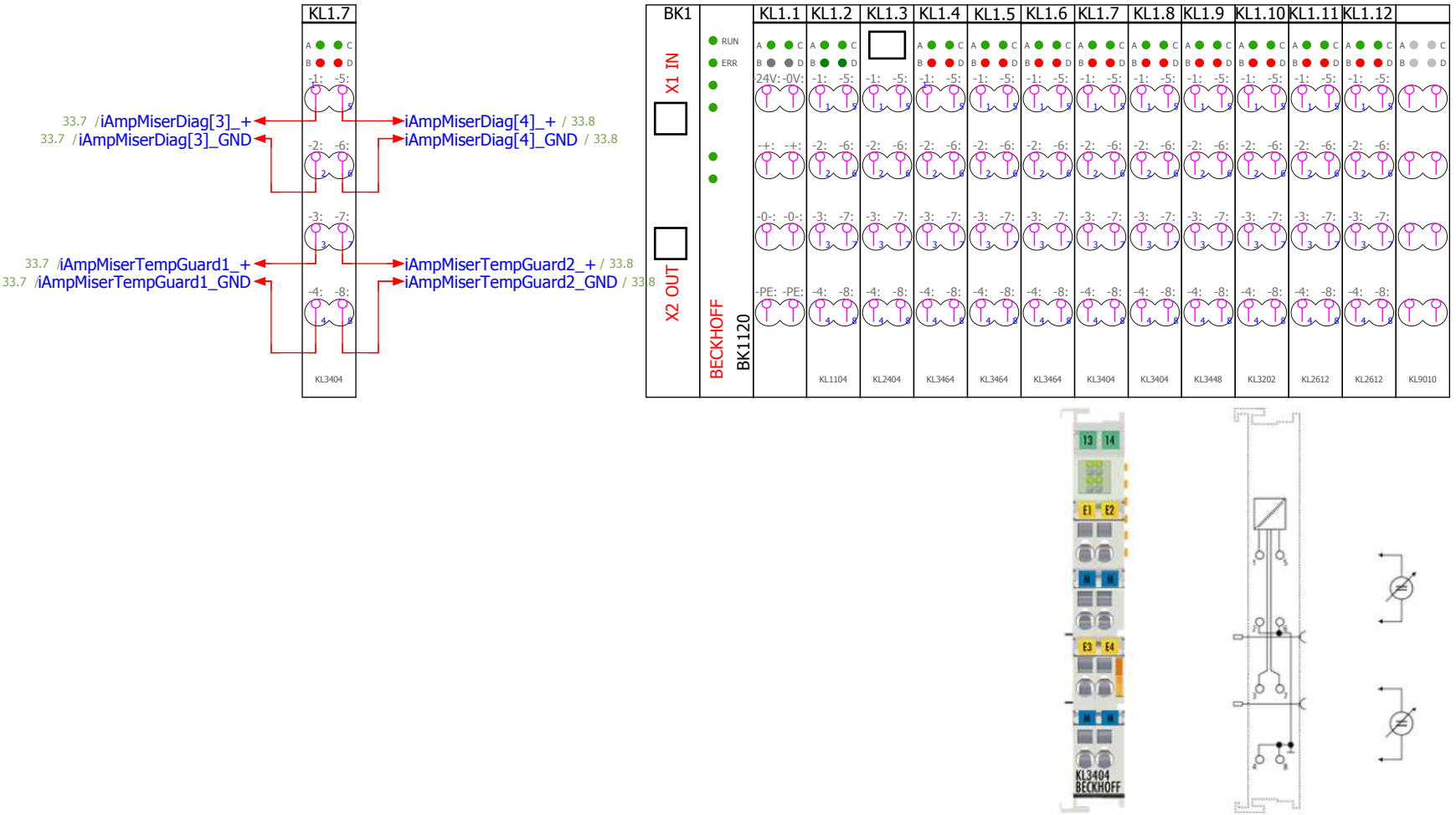

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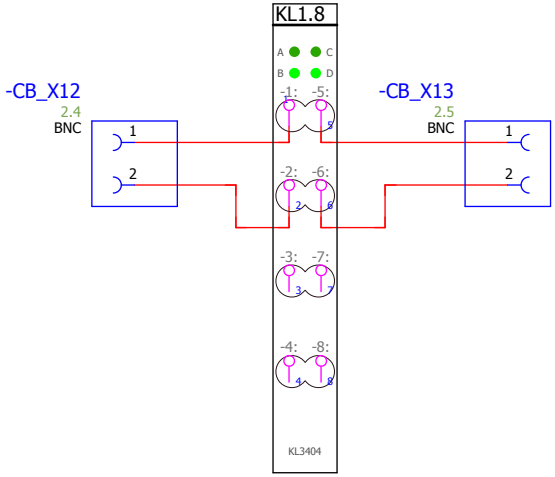

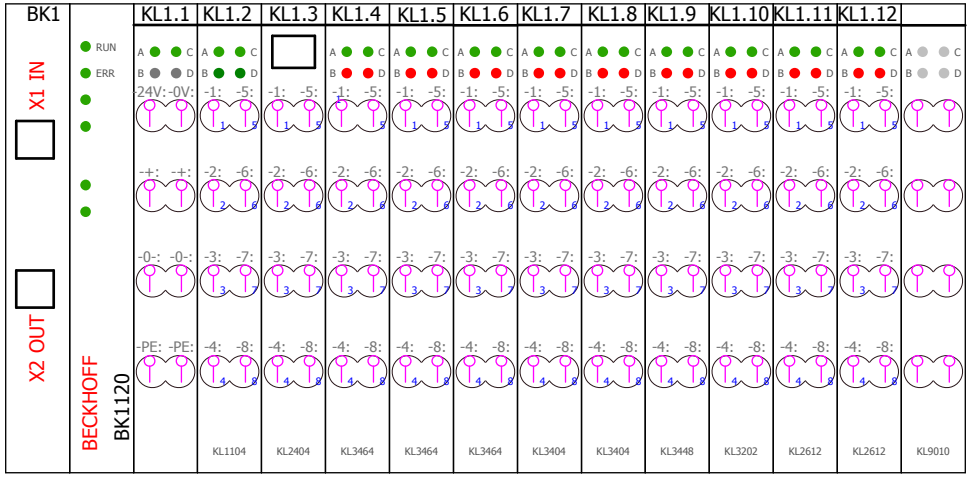

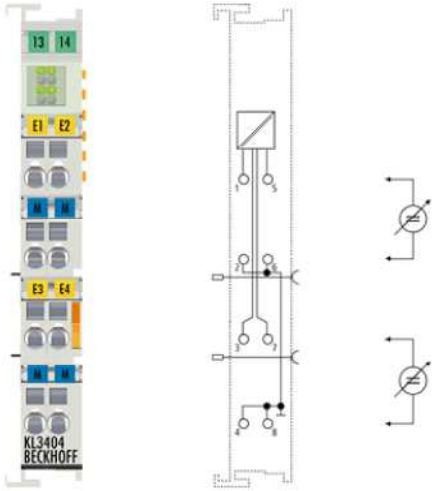

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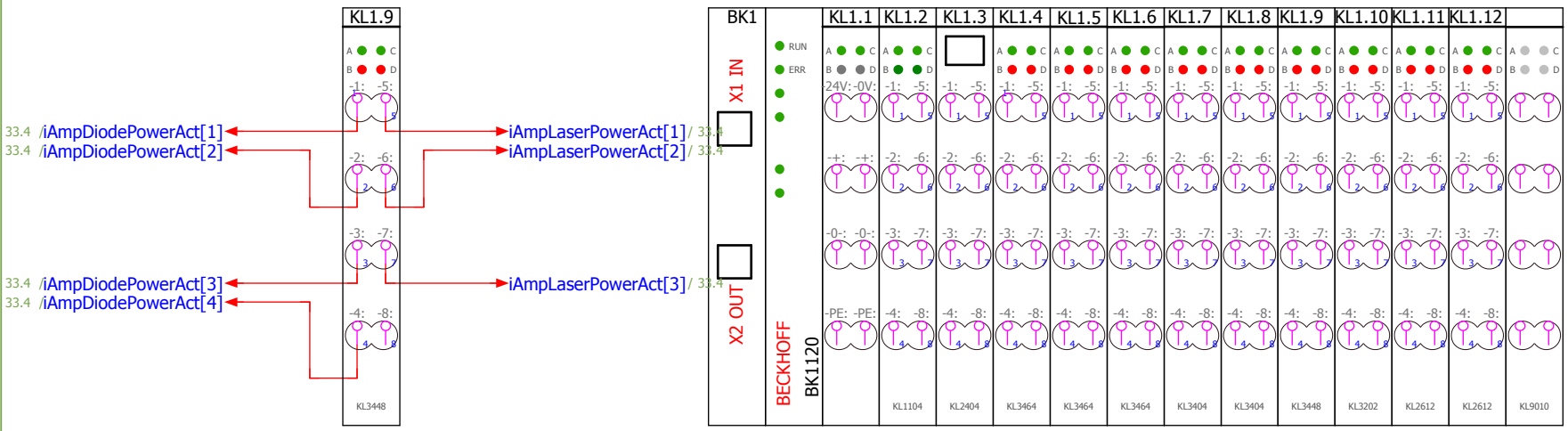

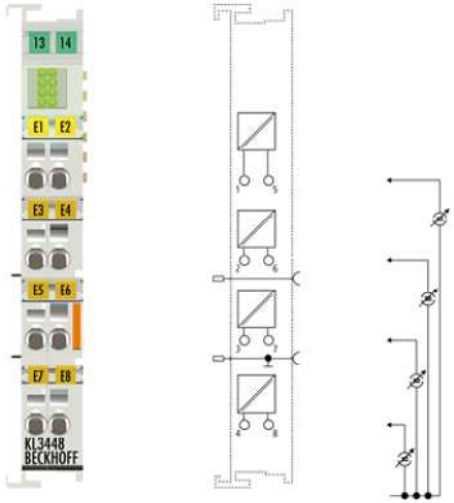

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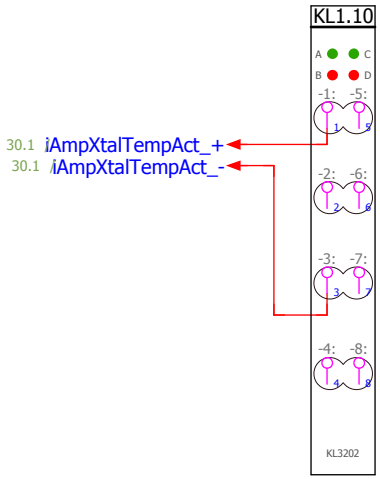
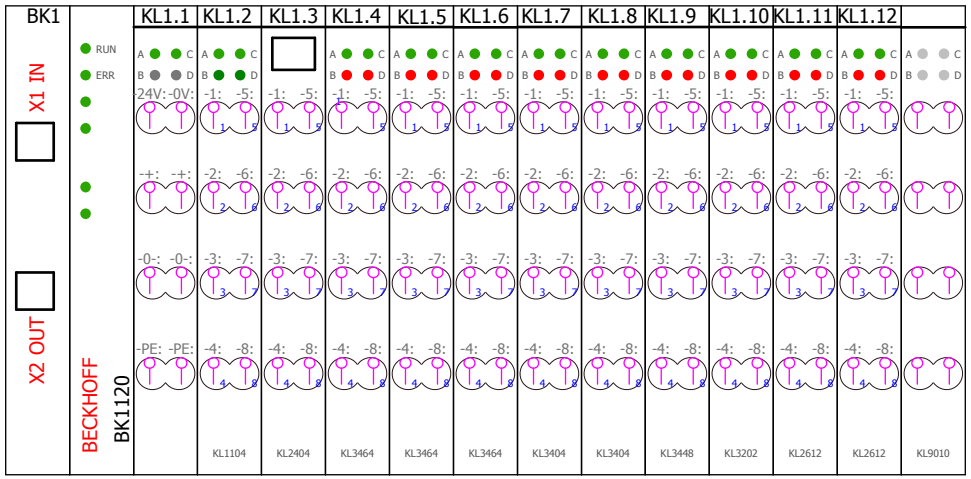
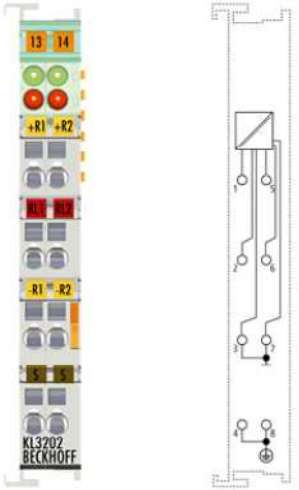
Modification	Date	Name	Original		Replacement for	Replaced by		Pg 34

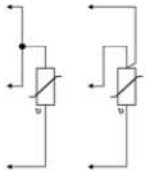
Laser Zentrum Hannover e.V.

CB PLC









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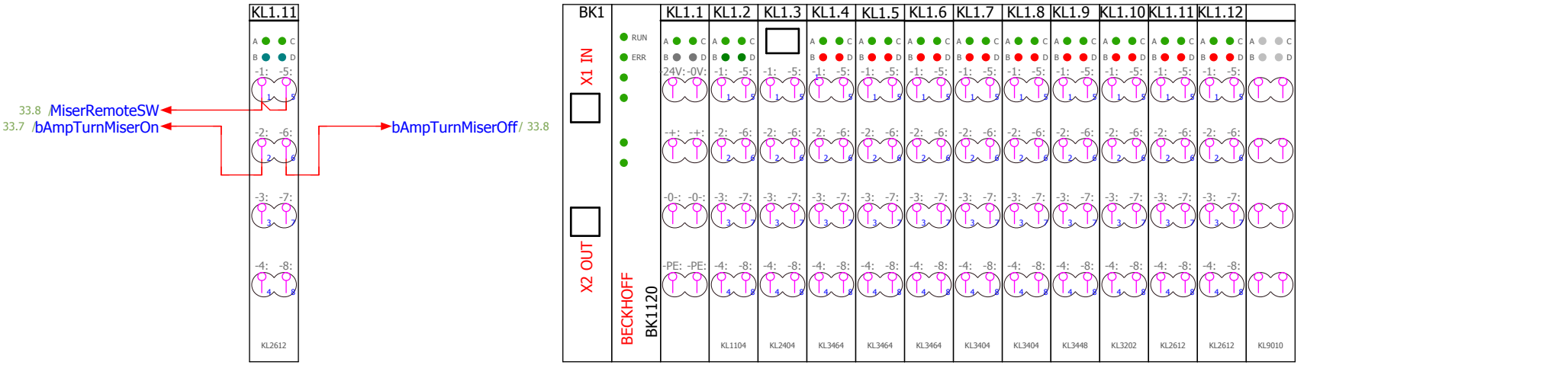

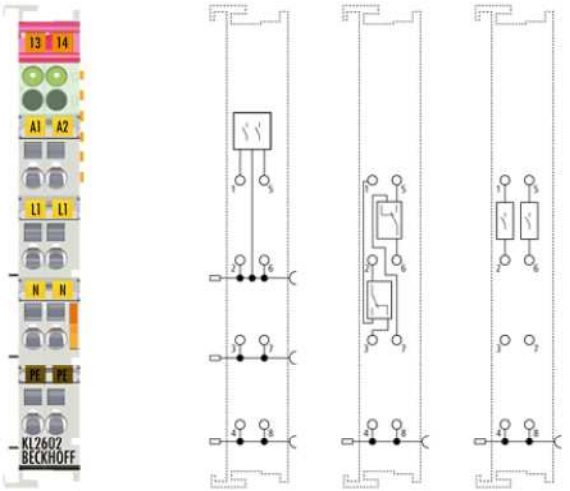

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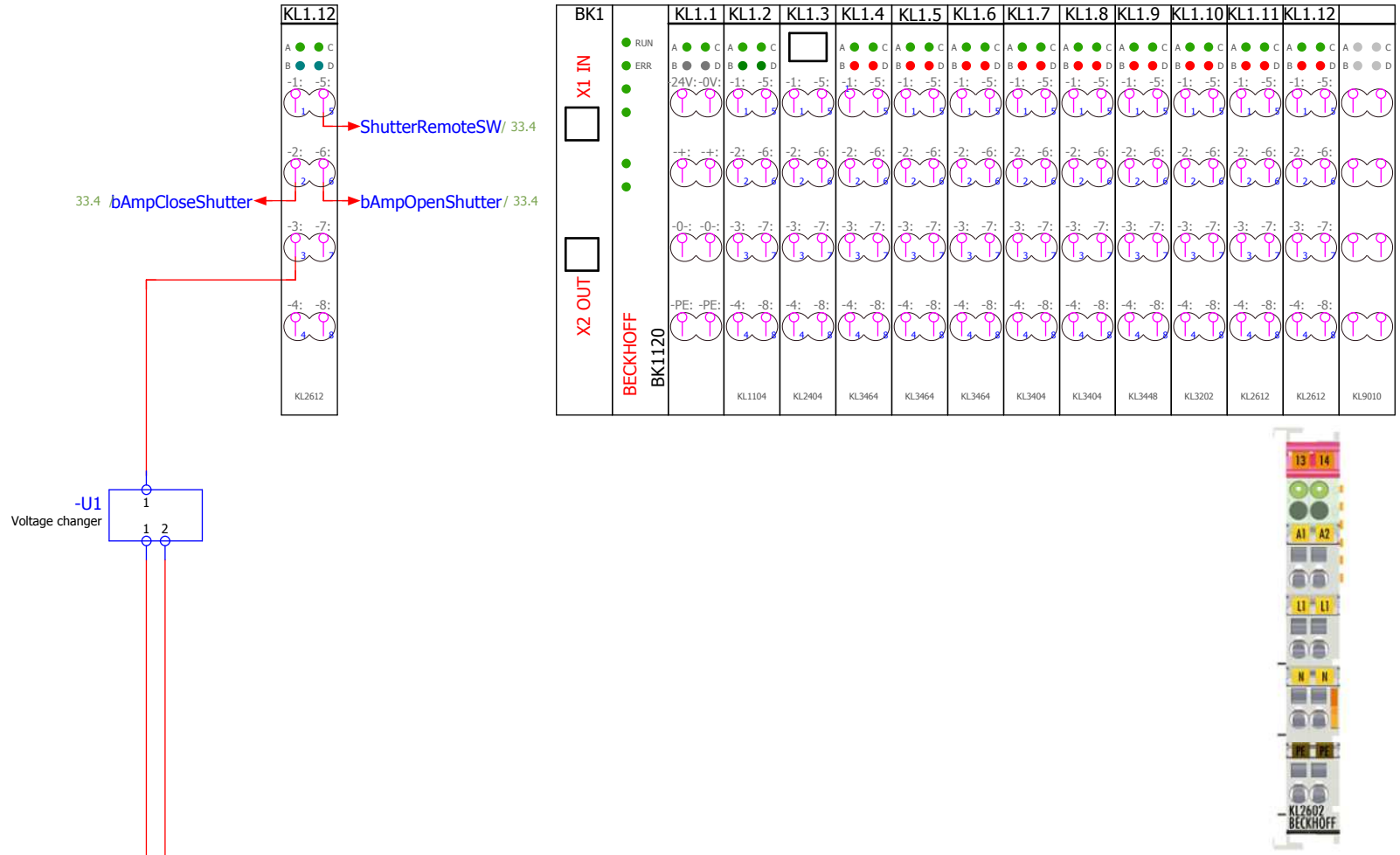
								Pg 34



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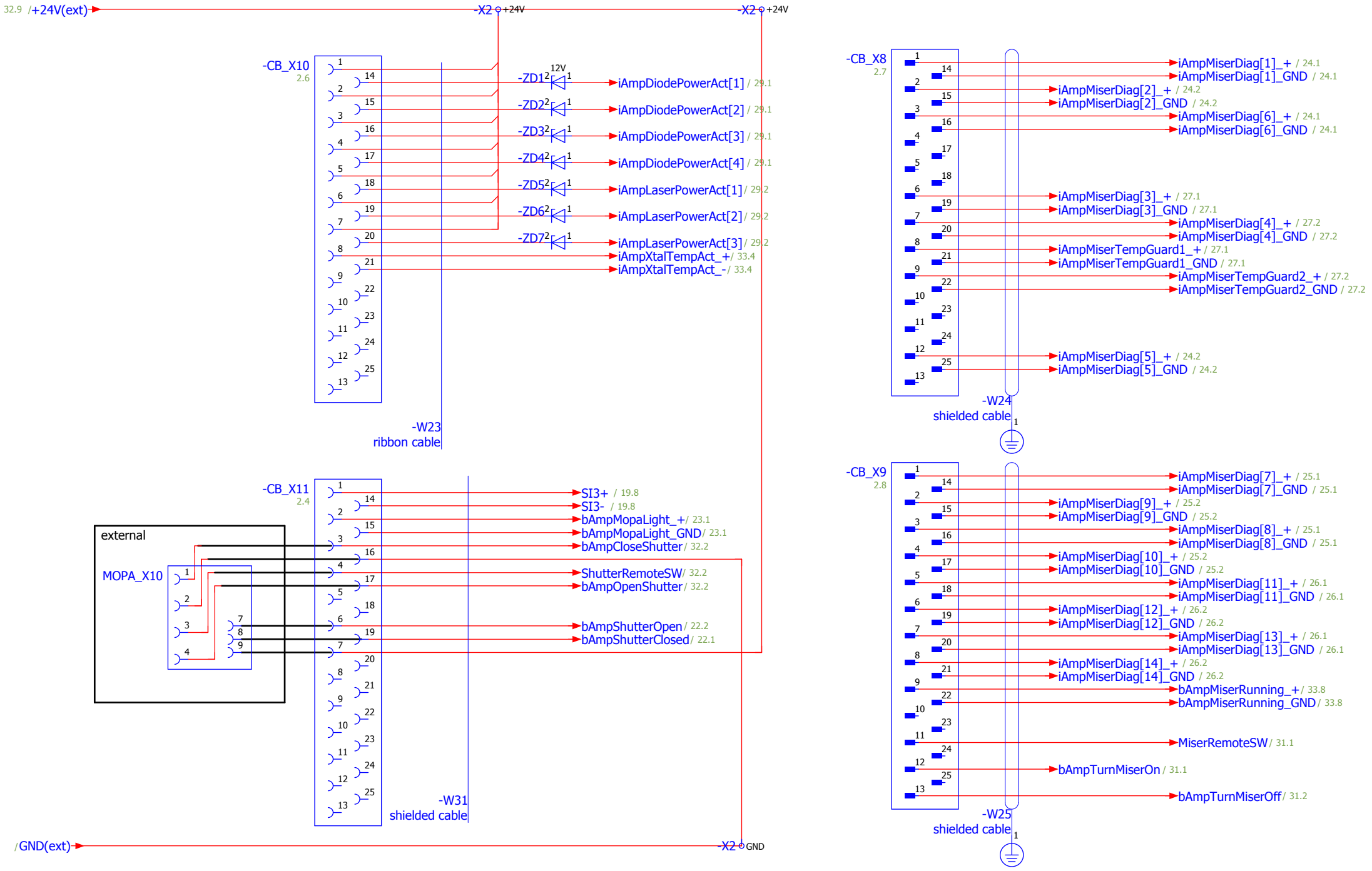
								Pg 34



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Modification	Date	Name	Original		Replacement for	Replaced by		Page 33
								Pg 34

Mephisto Product Line

User's Manual

Hannover, 10.10.2004

Version 4.6

InnoLight GmbH
Garbsener Landstr. 10
30419 Hannover
Germany
Tel.: +49 511 760 727-0
FAX: +49 511 760 727-99

- **When the product is received, the shipping container and its content should be inspected for any damage incurred during shipping. In case of damage, please inform InnoLight GmbH immediately!**

- **If any failure occurs, please contact InnoLight GmbH immediately! Do not open the modules! They do not contain any user serviceable parts!**

- **Read this manual carefully before starting up the laser!**

- **Before connecting or disconnecting any cables, switch off the control electronics!**

- **The Mephisto laser system is designed for applications in R&D fields. The laser must only be operated by trained personnel.**

- **Always wear laser goggles to protect your eyes!**

Hannover, 10.10.2004

Version 4.6

InnoLight GmbH
Garbsener Landstr. 10
30419 Hannover
Germany
Tel.: +49 511 760 727-0
FAX: +49 511 760 727-99

1 User Safety

1.1 Grounding the Power Supply

To minimize shock hazard, the power supply must be connected to an electrical ground. The power supply must be plugged into an approved electrical outlet using an appropriate AC power cable.

1.2 Line Voltage Selection

Before connecting the power cord, verify that the line voltage setting on the reverse side of the power supply agrees with your local line voltage.

1.3 Removing the Electronics Cover

Warning:
Dangerous voltages exist inside the power supply, even with the power switched off. Only qualified service personnel should remove the cover.

1.4 Laser Safety Warnings

Warning:
Exposure to laser radiation may be harmful. All apertures which can emit laser light in excess of levels which are considered safe are identified with the appropriate labels shown later in this section. Take extreme care when working in areas where these labels are placed.

Warning:
Always provide protective eyewear suitable for the laser's emission wavelength. The emission wavelength of your laser model may be 946 nm, 1064 nm, 1319 nm, or 1444 nm and is given in the data sheet.

Warning:
Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure. The use of optical instruments with these products may increase eye hazard.

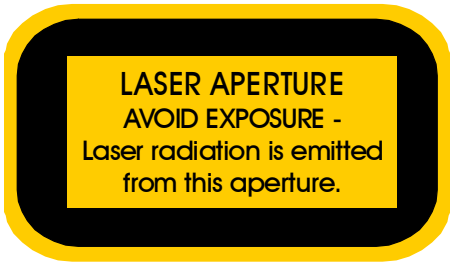
Caution:
Lasers may be damaged by improper setting of the current controls or by improper use of the modulation inputs. Check line voltage setting before connecting power.

Warning:
This laser product must not be used for any medical applications, whatsoever.

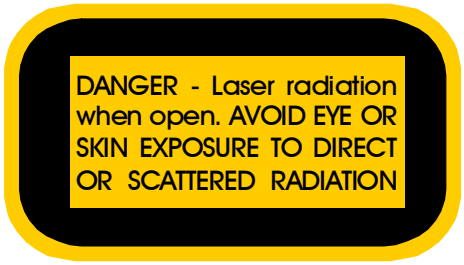
The positions of the laser safety and aperture labels affixed to the laser housing of the **Mephisto** Product Line are illustrated in the following Figure 1.1:

Figure 1.1: Positions of laser safety and aperture labels

Reproductions of the laser safety and aperture labels for lasers of the **Mephisto** Product Line are illustrated in the following Figure 1.2:



Label 1



Label 2

Label 3

Figure 1.2: Reproductions of laser safety and aperture labels

The maximum laser power level emitted from lasers of the **Mephisto** Product Line is 2 Watts in continuous wave operation. The nominal laser output power level for your laser model is given in the data sheet.

This laser product complies with the Federal Register 21 CFR 1040.10 Laser Safety Standard as applicable.

1.5 Servicing

There are no user replaceable parts inside the control electronics unit. Refer all servicing to qualified personnel or contact InnoLight GmbH.

1.6 Initial Activation

Read this manual carefully before operating the laser system !

The remote interlock connector must be installed at the rear panel of the control electronics unit (see Figure 2.3 and Figure 2.5). It is installed when shipped. If it is not in place, the yellow *Interlock* LED on the front of the Standard control electronics unit or the red *Error* LED on the front of the OEM control electronics unit will glow and the unit will be inoperable.

2 The **Mephisto** Laser System

2.1 Introduction

The **Mephisto** laser system consists of two self-contained units, the laser head (see section 2.2) and the control electronics unit (see sections 2.3 and 2.4). This manual is intended to provide some more detailed information on how to operate these devices properly.

Essentially the laser head consists of four components: One or two (depending on model) diode laser(s) which are electrically driven and provide the pump radiation for the monolithic Nd:YAG laser crystal. Some optics are required to focus the pump light into the Nd:YAG laser's fundamental mode. Optionally, a fraction of the generated Nd:YAG laser light is focused onto a photo detector to analyze variations of the emitted radiation. This signal, appropriately filtered and amplified by an electronic SMD board mounted inside the laser head, is fed to the diode laser pump source. Activating this feedback loop, the Nd:YAG laser's intensity noise is suppressed by a large amount close to the fundamental limit set by quantum noise (see section 4.7).

In order to operate the **Mephisto** laser system, the control electronics unit needs to be connected to the laser head. The provided electrical power is converted into coherent narrow bandwidth radiation with an efficiency of about 30 %. The remaining power heats the diode laser, which must be cooled to prevent overheating. Furthermore, the wavelength of the diode laser depends on the junction temperature. Therefore, temperature stabilization of the diode laser is essential. The wavelength of the Nd:YAG laser light also depends strongly on the crystal temperature, consequently the Nd:YAG laser crystal must be temperature stabilized as well. The control electronics unit is designed to provide all required subsystems to drive and control the **Mephisto** laser system**,** featuring:

- a *Laser Diode Driver* that provides a very stable, low noise injection current to the diode lasers up to a value of 3 A. This subsystem also contains the protection circuitry that is essential for reliable operation of the laser system (see sections 5.3 and 5.4) and a temperature controller that regulates the diode laser temperature.

- a *Precision Temperature Controller* that stabilizes the Nd:YAG crystal's temperature. Because of an integrated pre-stabilization stage, typical drifts of this controller are only a few 100 μK / min, corresponding to a variation of the laser frequency of less than 1 MHz / min.

- analog modulation inputs (BNC connectors) for diode laser current and laser crystal temperature to externally control output power and laser frequency of the **Mephisto** laser system.

- a diagnostics connector (D-Sub connector) to monitor all vital signals and voltages of the **Mephisto** laser system without opening the control electronics unit.

An OEM control electronics unit is available for customers, who do need the full functionality but not the full set of laser parameters to be permanently accessible as with the Standard control electronics unit.

2.2 Mephisto Laser Head

The dimensions of a laser head of the **Mephisto** Product Line are illustrated in the following Figure 2.1. The infrared laser beam is emitted from the laser aperture at the front side, which can be closed with a mechanical shutter.

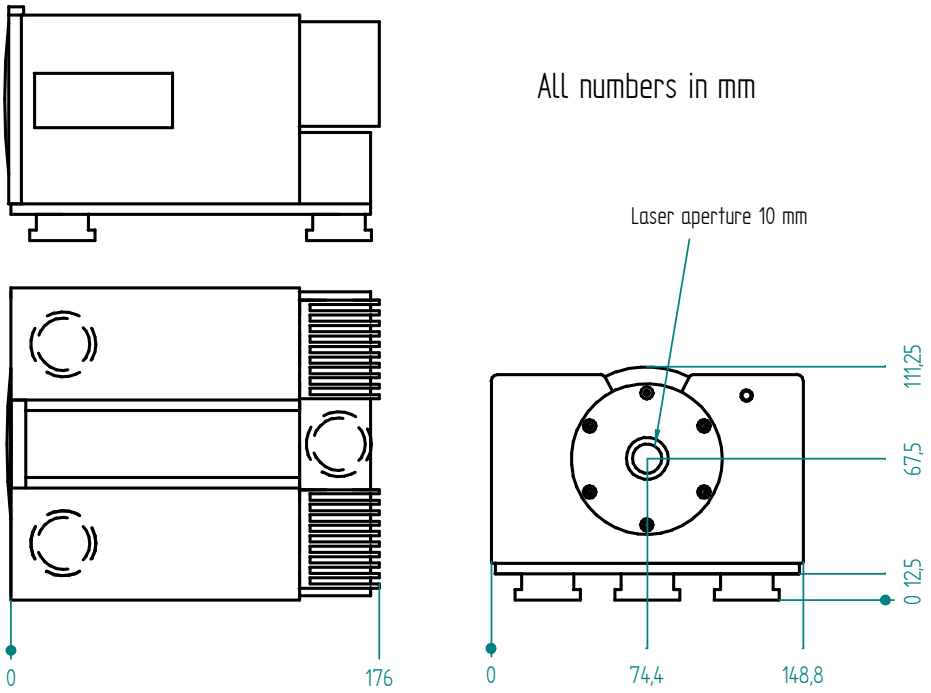


Figure 2.1: Dimensions of the **Mephisto** laser head

At the rear side of the laser head, a 37 pin D-Sub connector and a BNC connector are located. While the D-Sub laser connector (see section 6.1) is used to connect the laser head with the control electronics unit, the BNC connector can be used to apply a high voltage signal in the range –100 V to +100 V to a PZT element on the laser crystal for fast tuning of the laser frequency (see section 4.2).

The two following sections illustrate the front and rear panels of both the Standard and OEM control electronics units. Having the same internal functionality, the OEM control electronics unit is intended for customers, who want to operate the **Mephisto** laser system with identical laser parameters most of the time, while the Standard control electronics unit provides the possibility to easily access and vary all laser parameters of interest at any time.

The power ratings illustrated in Figure 2.3 and Figure 2.5 are just one possible configuration to be used e.g. in Western Europe.

2.3 Standard Control Electronics Unit

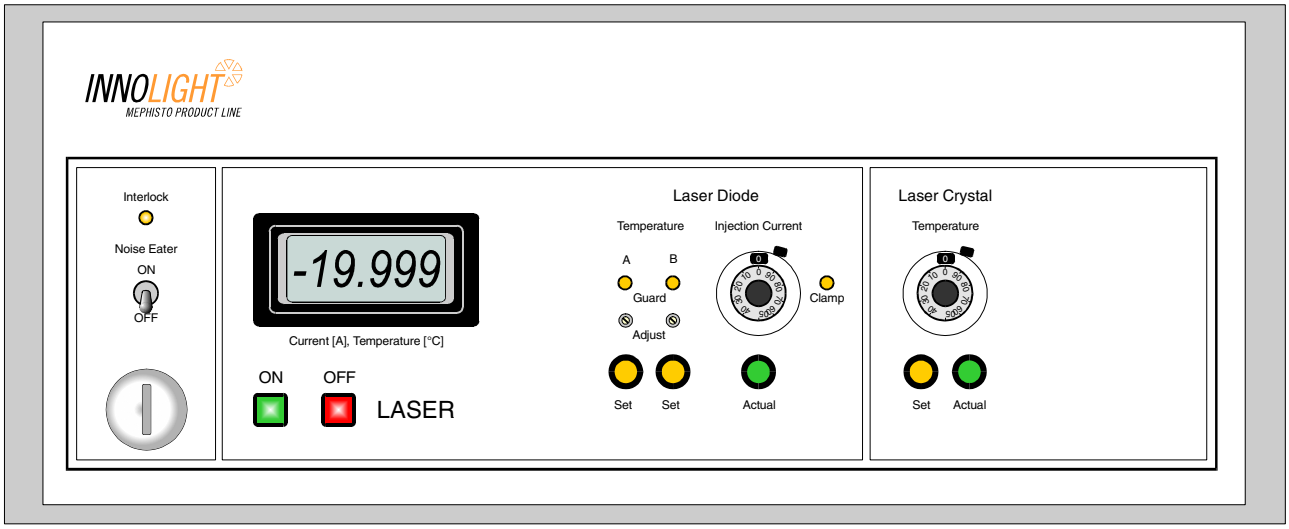


Figure 2.2: Front panel of the **Mephisto** Standard control electronics unit

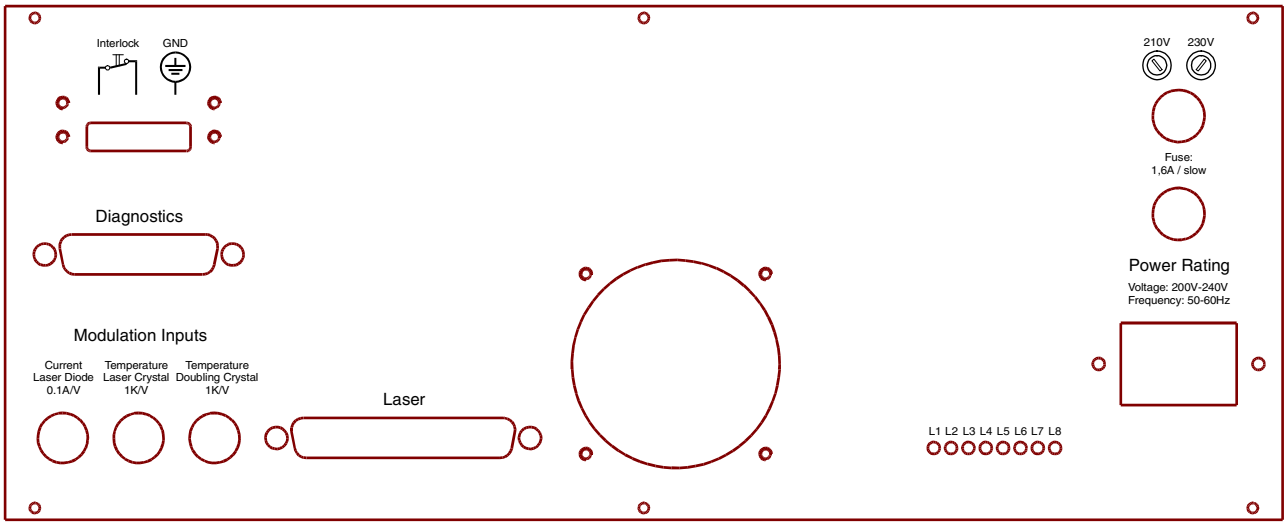


Figure 2.3: Rear panel of the **Mephisto** Standard control electronics unit

The pin configuration of the laser and diagnostics connectors as well as the voltage indicators (L1-L8) are described in section 6.

2.4 OEM Control Electronics Unit

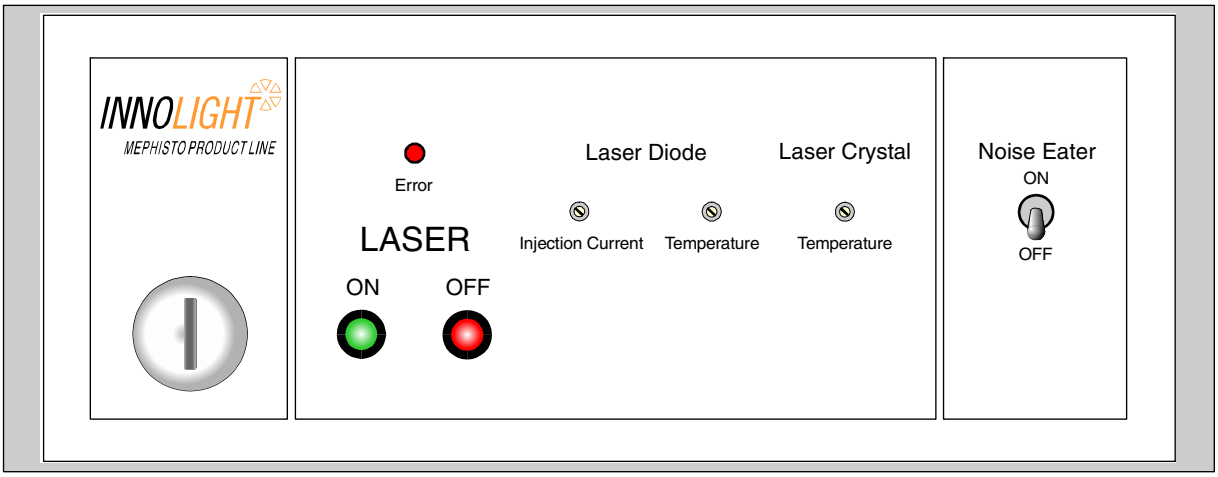


Figure 2.4: Front panel of the **Mephisto** OEM control electronics unit

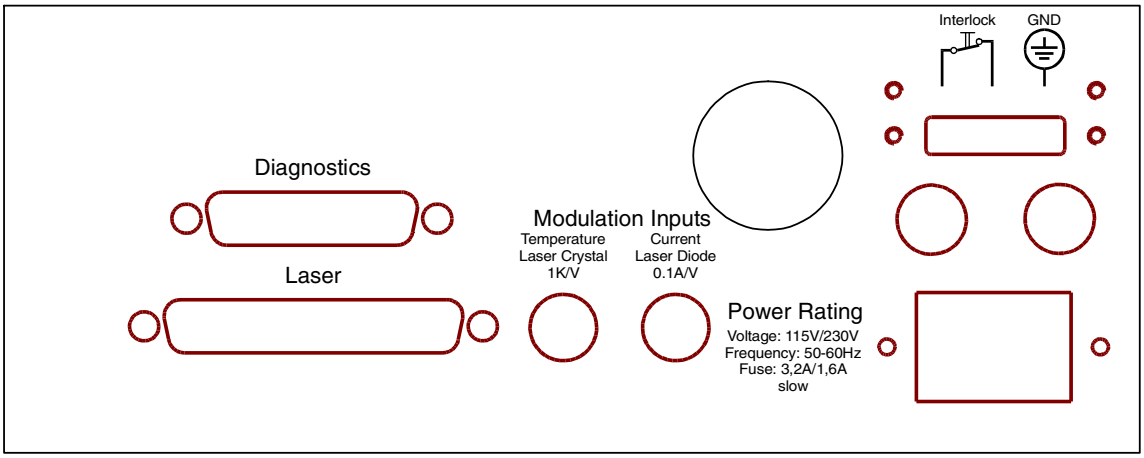


Figure 2.5: Rear panel of the **Mephisto** OEM control electronics unit

The pin configuration of the laser and diagnostics connectors is described in section 6.

3 Operating the **Mephisto** Laser System

3.1 Diode Laser Safety Precautions

Diode lasers are very sensitive devices. They consist of semiconductor material, consequently they should not be overheated. For laser operation a resonator is required, in most diode lasers (including these high power lasers) the crystal end faces serve as the resonator mirrors. Therefore, these surfaces need to be perfectly plain and clean. This is normally accomplished by cutting the semiconductor wafer along a crystal plane and by hermetically sealing the case protecting the laser from the environment. The crystal end faces are very sensitive to transient current fluctuations. Even short spikes (shorter than 1 ns) with peak current larger than the normal operation current will build up an excessively intense photon field inside the resonator, destroying the crystal surface. In this event only spontaneous emission remains, the laser behaves like an ordinary LED. Due to this possibility, the laser has to be protected against current spikes. In the **Mephisto** system, this is accomplished by a sophisticated electronic protection circuitry.

Static charge is also a well known killer of diode lasers. For this reason, the connections of the diode laser should always be shorted, if not in operation. When the laser head is not connected to the electronics unit, a built-in relay shorts the diode pins. After the control electronics unit is connected and switched on, the relay opens the short circuit when the signal power supply reaches its nominal value, ensuring proper operation of the driver circuitry. The driver is still in the inactive mode, and a power MOS-FET shorts the diode laser. Switching the unit into the active mode, the MOS-FET becomes nonconductive and the driver starts working.

If the signal power drops below its nominal value (e.g. caused by mains failure) the driver switches back to the inactive mode. This happens ***before*** the relay shorts the diode laser, so that mechanical ringing of the relay cannot cause any current spikes.

For further protection of the diode laser, a current limiting circuitry is included. The *Injection Current* is restricted to the range from zero to the internally set current limit. It is not possible to exceed this current limit with the dial on the front panel. Theoretically, this could be achieved by applying a positive voltage to the power modulation input at the back panel of the electronics unit. However, in this case, the yellow *Clamp* LED at the front panel of the Standard control electronics unit or the red *Error* LED at the front panel of the OEM control electronics unit will glow, and the actual *Injection Current* will ***not*** go beyond the internally set current limit.

To prevent the diode lasers from overheating, the control electronics unit contains a *Temperature Guard* that monitors deviations between the *Set Temperature* and the actual diode laser temperature and switches the driver into inactive mode in case of overheating (see Section 5.3).

3.2 Installing the Mephisto Laser System

Before connecting the power cord, verify that the line voltage setting on the reverse side of the power supply agrees with your local line voltage. If your laboratory environment features an interlock switch that remains off under unsafe conditions, connect it to the two left pins of the three-pole screw-type connector at the rear of the control electronics unit (see Figure 2.3 or Figure 2.5). For activating the diode driver, these pins have to be shorted. You can use the right-hand pin to ground the unit, e.g. by connecting it to the metal laboratory breadboard.

For mounting the **Mephisto** laser head on an optical table or a breadboard, use the three holding forks to fix the three pedestals. Further clamping or squeezing of the laser head is not recommended, as it may cause temporary misalignments of the optics inside. The laser head should be mounted with free surroundings.

The two units of the **Mephisto** laser system, the laser head and the control electronics unit, are to be connected only by using the suitable cable shipped with the laser system.

Caution:
Before connecting the two units, make sure the control electronics unit is switched off.

3.3 Turning the Laser on and off

For proper operation of the **Mephisto** laser system, the following activation sequence is recommended for users of the Standard electronics unit. All controls mentioned are located on the front panel of the **Standard** control electronics unit (see Figure 2.2):

1. Use the main key switch to turn on the unit. The red *OFF* button will glow and the fan will be operating.

2. Make sure, the yellow *Interlock, Guard,* and *Clamp* LEDs are not glowing.

3. Check the *Set Temperature* of the diode laser(s) by pushing the *Set* button(s) in the section *Laser Diode*. Compare the values with those given in the data sheet of the laser.

4. Check the *Set Temperature* of the Nd:YAG laser crystal by pushing the *Set* button in the section *Laser Crystal*. The correct operation temperature depends on your requirements and may be around 25 °C (consider recommendations in section 3.4).

5. Allow about 60 seconds for the temperature controllers to stabilize.

6. Make sure that the 10-turns dial of the *Injection Current* is in its zero position.

7. Choose the *Actual* injection current to be displayed at the monitor by pushing the green button in the section *Laser Diode*.

8. Activate the diode driver by pressing the green *ON* button. The button will glow green.

9. Increase the *Injection Current* until the desired value is displayed at the monitor (see data sheet).

Go through the following steps to switch off the **Mephisto** laser system:

1. Decrease the *Injection Current* to 0 mA.
2. Deactivate the diode driver by pressing the red *OFF* button. The button will glow red.
3. Switch the unit off with the main key switch.

For customers of the **OEM** control electronics unit (see Figure 2.4), the following, somewhat shorter procedure is valid:

1. Use the main key switch to turn on the unit. The red *OFF* button will glow.
2. Make sure, the red *Error* LED is not glowing.
3. Allow about 60 seconds for the temperature controllers to stabilize.
4. Activate the diode driver by pressing the green *ON* button. The green LED will glow.

Go through the following steps to switch off the **Mephisto** laser system:

1. Deactivate the diode driver by pressing the red *OFF* button. The red LED will glow.
2. Switch the unit off with the main key switch.

The preset injection current, temperatures and error signals of the OEM control electronics unit can be monitored at the diagnostics connector at the rear panel of the unit (see Figure 2.5). The pin configuration and the voltage coefficients are described in Table 6.3 of section 6.2. To change these preset values, use the individual trimmers at the front panel (see Figure 2.4).

Both the Standard and OEM control electronics units feature a soft-start that smoothly increases / decreases the laser diode's current if the *LASER ON / OFF* buttons are pressed. Because of the limited heat conductivity inside the diode laser's heat sink, a rapid increase of the injection current has to be avoided.

Caution:
Lasers may be damaged by improper setting of the current controls or by improper use of the modulation inputs.

3.4 Recommended Operation

The laser head as well as the control electronics unit should not be operated in an environment warmer than 25 °C, which would result in a lot of stress for the electronics and diminished operation efficiency of the laser.

The laser head contains several optical components which are carefully aligned for best performance. Therefore, the laser head should be handled very carefully; any mechanical shock is hazardous ! Misalignment will cause the optical power to decrease and should not be cured by the operator ! Check the output power using a power meter.

In the case of low optical output power or poor beam quality, please contact InnoLight GmbH immediately. Do not attempt to fix the problem on your own!

When mounting the laser head, any mechanical stress inside the case can cause temporary misalignment of the optics. Thus squeezing the case should be prevented.

Warning:
Be aware that the laser might disturb equipment that is sensitive to magnetic fields.

Be careful when operating the laser head in humid environment. Condensation of water must be strictly avoided, since the optics cannot be cleaned by the operator.

Caution:
The *Set Temperature* of the Nd:YAG crystal should never be more than 5 °C below room temperature. Under humid conditions, only operation above room temperature is recommended.

Warning:
Keep in mind that a hazardous amount of invisible laser radiation might be diffracted in any direction!

Warning:
Always wear suitable laser goggles to protect your eyes!

3.5 Trouble Shooting

The control electronics unit for the **Mephisto** laser system includes a sophisticated safety circuitry to protect the diode lasers against current spikes or overheating and switches the diode driver into inactive mode in case of problems. This is indicated by the yellow LEDs at the front panel of the Standard control electronics unit and the red *Error* LED of the OEM control electronics unit, respectively. Check for the following possible causes:

- *Interlock*

Diagnosis: The two pins of the Interlock connector at the rear panel of the control electronics (see Figure 2.3 and Figure 2.5) are not connected.

Reaction: Short the two pins of the Interlock connector or check the Interlock switch in your laboratory.

- *Guard*

Diagnosis: The temperature controller is not able to stabilize the diode laser temperature at the given value.

Reaction: Try to increase the set temperature for the diode laser slightly using the trimmer at the front panel of the control electronics unit, especially if it is set below room temperature. Otherwise contact InnoLight GmbH.

- *Clamp*

Diagnosis: The injection current of the diode lasers is driven above its internal limit.

Reaction: Reduce the injection current by about 50 mA using the dial or trimmer at the front panel of the control electronics unit or reduce the voltage at the power modulation input at the rear panel of the control electronics unit (see sections 2.3 and 2.4).

The presence of all supply voltages required for reliable operation of the **Mephisto** laser system is indicated by a set of LEDs at the rear panel of the Standard electronics unit (see Figure 2.3).

If any of the LEDs L1 to L8 is not glowing, the corresponding supply voltage is not present (see section 6.3) and the laser system will not work properly. In that case contact InnoLight GmbH.

4 Laser Specifications

The general specifications apply to all continuous wave (cw) lasers of the **Mephisto** Product Line and are summarized in the following Table 4.1:

General specifications:	
Beam quality	TEM_{00} (M^2 <1,1)
Beam roundness	1,1
Thermal tuning coefficient [GHz/K]	-3
Thermal tuning range [GHz]	30
Thermal response bandwidth [Hz]	1
PZT tuning coefficient [MHz/V]	>1
PZT tuning range [MHz]	± 100
PZT response bandwidth [kHz]	100
Emission spectrum	single-frequency
Spectral linewidth [kHz/100 ms]	1
Coherence length [km]	>1
Frequency drift [MHz/min]	1
Relative Intensity Noise, RIN [dB/Hz]	<-100
Noise eater option, RIN [dB/Hz]	<-150
Intensity noise, 10 Hz to 2 MHz [% rms]	< 0,1
Waist location (inside laser head) [mm]	90
Laser head size, w · h · d [cm]	14,9 · 11,1 · 17,6
Laser head weight [kg]	2
Standard electronics size, w · h · d [cm]	35 · 14 · 34
Standard electronics weight [kg]	10
OEM electronics size, w · h · d [cm]	24 · 9 · 34
OEM electronics weight [kg]	3,5

Table 4.1: General specifications of the **Mephisto** Product Line

The individual specifications of the different laser models of the **Mephisto** Product Line are summarized in Table 4.2:

Model specifications:	
Mephisto QTL, power @ 946 nm [mW]	100[1,3], 200[1], 500[1]
Mephisto YLF, power @ 1053 nm [mW]	100[1,3], 300[1]
Mephisto, power @ 1064 nm [mW]	500[1-4], 1000[1-3], 1200[1-3], 2000[1,2]
Mephisto MIR, power @ 1319 nm [mW]	100[1-3], 200[1-3], 500[1,2]
Mephisto ES, power @ 1444 nm [mW]	100[1,3], 200[1]

Options:

[1] = NE (Noise Eater); [2] = FC (Fiber Coupling); [3] = OEM Electronics; [4] = ETR (Extended Tuning Range)

Table 4.2: Model specifications of the **Mephisto** Product Line

Some of the laser specifications and the available options of the **Mephisto** Product Line are illustrated in the following sections.

4.1 Beam Quality

The following Figure 4.1 illustrates a typical beam quality measurement of a **Mephisto** laser operating at 1064 nm. The laser beam is focused with a lens and the beam radius of the caustic is measured at various distances with a laser beam analyzer.

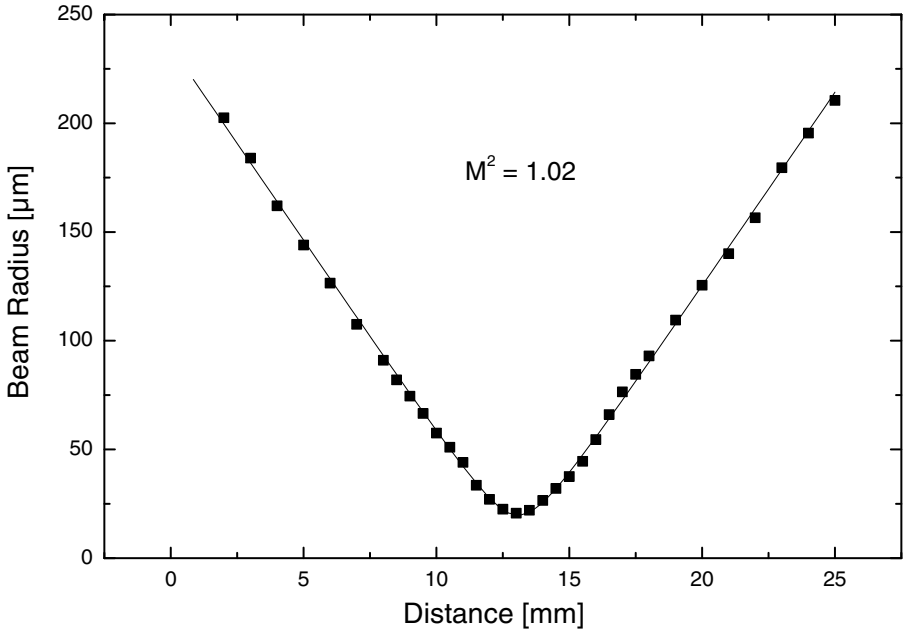


Figure 4.1: Beam quality measurement of a **Mephisto** laser

The filled squares represent the measurement points while the solid line is a theoretical calculation with the beam quality factor "M^2" as fitting parameter. Using the least error squares approach for determining the fitting parameter, an "M^2" factor of 1.02 is obtained. Hence, the output beam of the laser is 1.02 times "diffraction limited".

4.2 Frequency Tuning Capabilities

The frequency of the **Mephisto** laser can be tuned by changing the temperature of the monolithic laser crystal. This can either be done directly at the front panel of the control electronics unit using the appropriate dial or trimmer (see Figure 2.2 and Figure 2.4) or by applying a voltage to the Laser Crystal temperature modulation input at rear panel of the control electronics unit (see Figure 2.3 and Figure 2.5).

The typical tuning characteristic of a standard **Mephisto** laser operating at 1064 nm is shown in the following Figure 4.2. The filled dots represent operation on a single longitudinal frequency, while the open dots indicate the mode-hops, where the laser frequency changes from one longitudinal mode to the next.

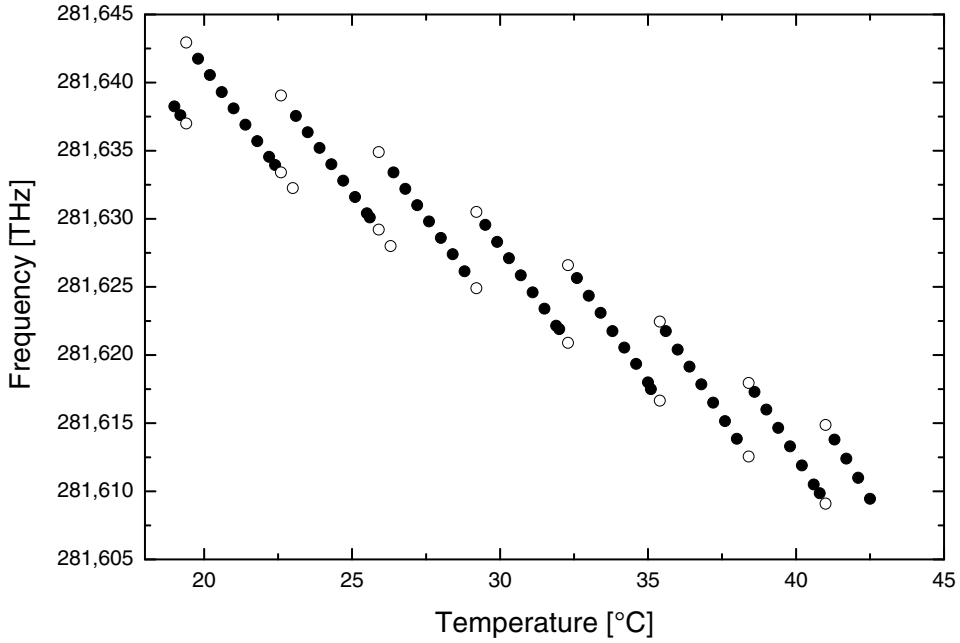


Figure 4.2: Typical frequency tuning by crystal temperature of a **Mephisto** laser at 1064 nm

As can be seen, the laser frequency can be tuned continuously by 6 – 8 GHz between the mode-hops covering an overall frequency tuning range of more than 30 GHz. The thermal tuning coefficient at 1064 nm is about –3 GHz / °C, for longer wavelengths it is slightly smaller. However, due to the large time constants of the thermal tuning, the response bandwidth is limited to fractions of a Hertz.

A significantly larger continuous tuning range of more than 15 GHz at a reduced output power can be achieved with the *Extended Tuning Range* (ETR) option as illustrated in the next Figure 4.3:

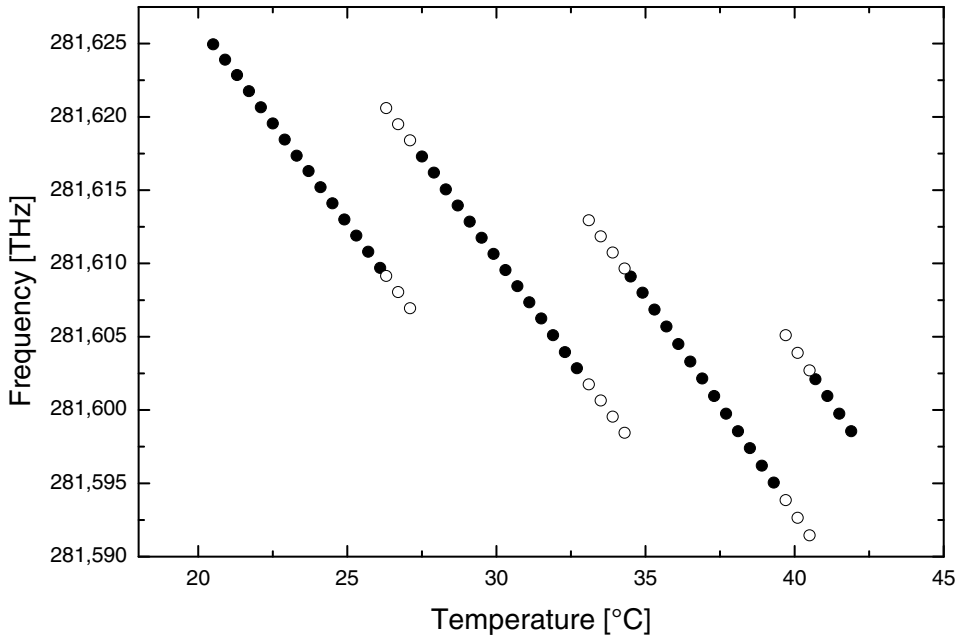


Figure 4.3: Typical frequency tuning by crystal temperature of a **Mephisto** laser at 1064 nm with ETR option

Fast frequency tuning of a **Mephisto** laser can be achieved by applying a high voltage signal in the range of –100 V to +100 V to a PZT crystal element on the laser crystal, using the BNC connector at the rear side of the laser head (see Figure 2.1). Higher voltages will misalign the laser cavity or even destroy the PZT crystal. Especially RF signals will heat up the PZT and damage it.

Depending on the actual laser crystal and the modulation frequency, the PZT tuning coefficient is about 1 to 2 MHz / V with a response bandwidth of about 100 kHz. The combination of the slow temperature tuning with a large range and the fast tuning with a high bandwidth is ideally suited for stabilizing the laser frequency to reference cavities or molecular absorption lines.

4.3 Emission Spectrum

A common feature of all models of the **Mephisto** Product Line is the reliable emission on a single longitudinal frequency. This can be investigated using an optical spectrum analyzer like a confocal Fabry Perot Interferometer (FPI) as illustrated in the following Figure 4.4. The free spectral range (FSR) of the device was 2 GHz as indicated:

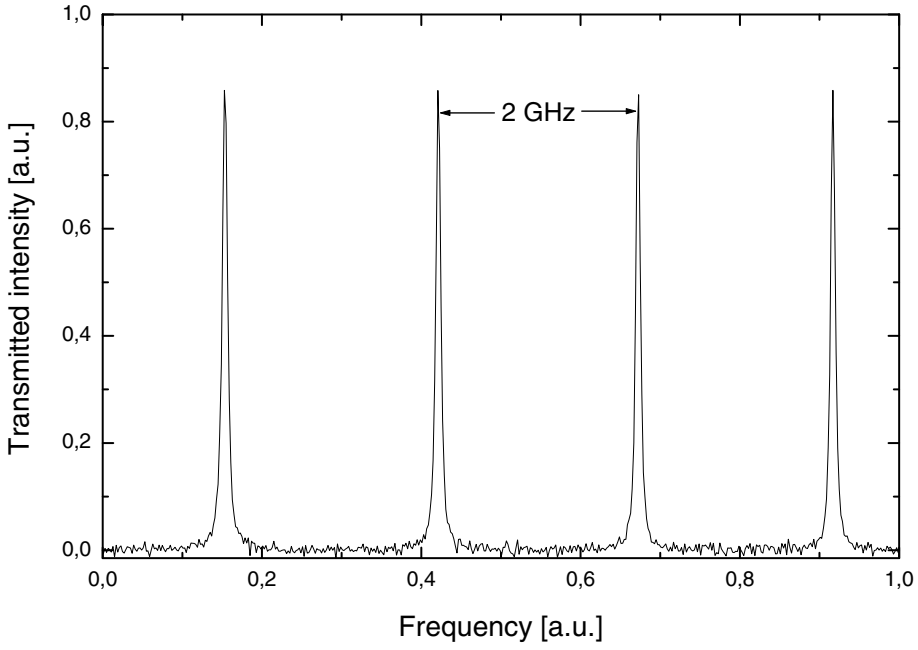


Figure 4.4: Emission spectrum of a **Mephisto** laser using a scanning Fabry Perot interferometer (FPI)

The absence of any peaks between the main resonances of the interferometer clearly indicates the operation on a single longitudinal frequency. Hence, the **Mephisto** laser system resembles the optical equivalent of a quartz oscillator in the frequency range of nearly 300 THz, providing the required precision for applications like interferometry or spectroscopy.

4.4 Spectral Linewidth

Another important feature of the **Mephisto** Product Line is the extremely small spectral linewidth of the laser due to the monolithic cavity. An upper limit for the intrinsic spectral linewidth of such a laser can be obtained by optically heterodyning two identical lasers and analyzing the beat signal with a spectrum analyzer as illustrated in the following Figure 4.5:

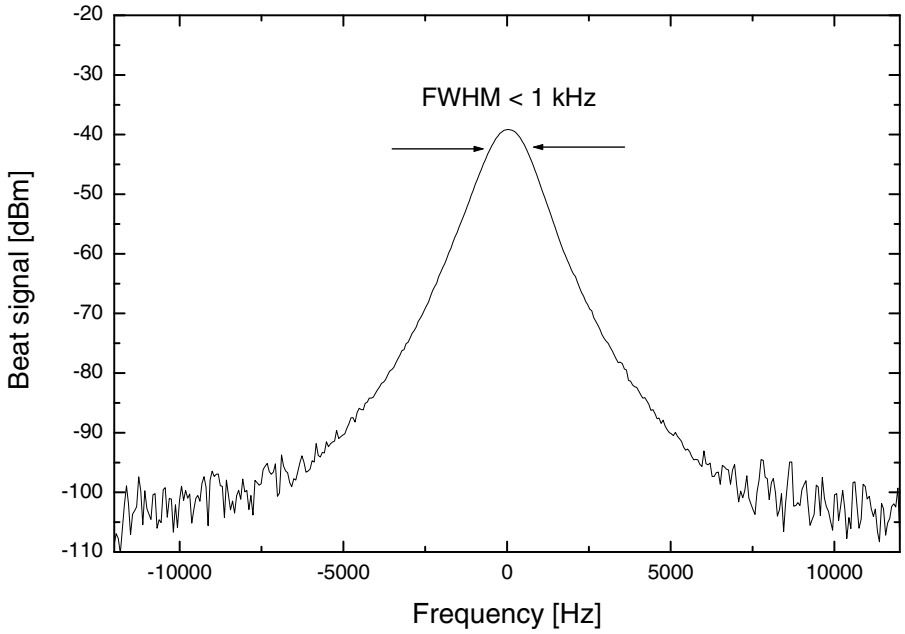


Figure 4.5: Heterodyne beat signal of two identical **Mephisto** lasers

The typical full width at half maximum (FWHM) or –3 dB linewidth derived from such a measurement is about 1 kHz, giving an upper limit for the intrinsic spectral linewidth of the two individual lasers, limited by the spectral resolution bandwidth of the measurement system.

The combination of reliable single longitudinal frequency operation at nearly 300 THz with an extremely small linewidth of less than 1 kHz is the key feature for using lasers of the **Mephisto** Product Line as optical length and frequency standards.

4.5 Beam Polarization

The output beam of the **Mephisto** Product Line is elliptically polarized with an intensity ratio $I_S/I_P \cong 5/1$ and the main axis oriented perpendicular to the mounting table (s-pol). As this polarization state represents an Eigenmode of the monolithic ring laser cavity, it can be transformed without loss into any linear polarization state by means of a suitable combination of quarter-wave and half-wave plates. The resulting polarization extinction ratio is typically ~ 300/1.

4.6 Frequency Drift

As the frequency of a **Mephisto** laser at 1064 nm can be tuned with a large temperature tuning coefficient of more than 3 GHz per degree (see section 4.2), temperature controllers with micro-kelvin stability are required to obtain a high frequency stability and a low frequency drift of the free running laser. This can be investigated, again by optically heterodyning two identical single-frequency lasers, one actively stabilized to a reference cavity or a molecular absorption line, the other one just passively stabilized.

The following Figure 4.6 illustrates such a beat frequency measurement of two identical **Mephisto** lasers using a precision frequency counter over a period of three hours:

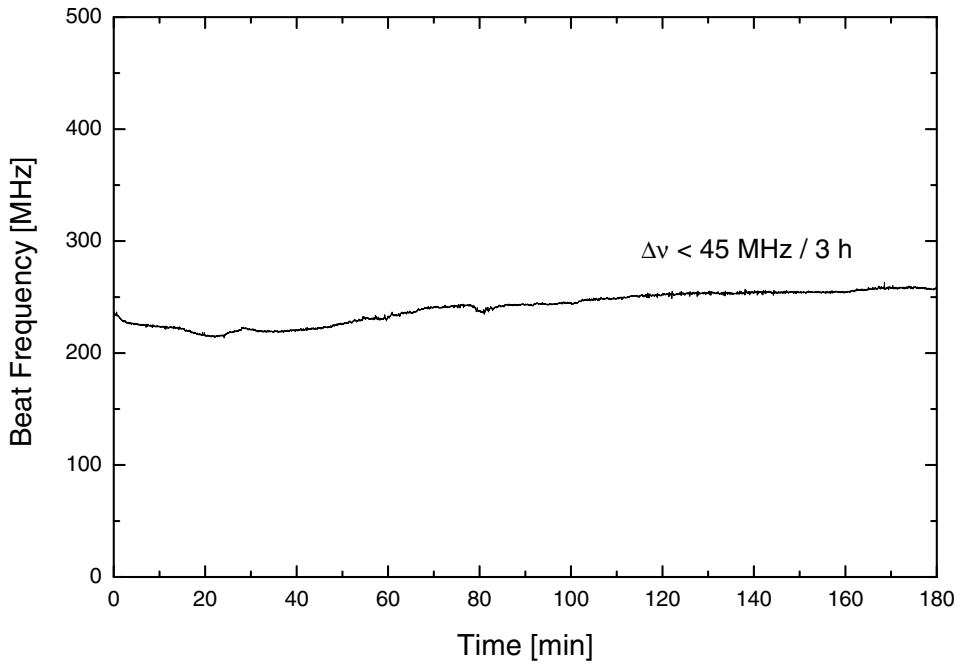


Figure 4.6: Frequency drift of a free running **Mephisto** laser against a stabilized reference system

The resulting frequency variation of the free running laser over the full period is less than 45 MHz, corresponding to a relative frequency stability of about $1.6 * 10^{-7}$. If a higher frequency stability is required for a certain application, the **Mephisto** Product Line provides the necessary inputs for active frequency stabilization to reference cavities or molecular absorption lines (see section 4.2).

4.7 Relative Intensity Noise (RIN)

Optionally, all lasers of the **Mephisto** Product Line can be equipped with an integrated intensity noise reduction system. This option reduces intensity fluctuations of the laser beam by several orders of magnitude. These fluctuations are largely due to a phenomenon called relaxation oscillations, owing to the ability of the laser's energy to oscillate between atomic level population and laser cavity field.

The spectrum of these fluctuations resembles the spectral behavior of a white-noise-excited classical oscillator, featuring a large peak and a significant amount of low frequency noise as illustrated in the trace "Free running" of the following Figure 4.7:

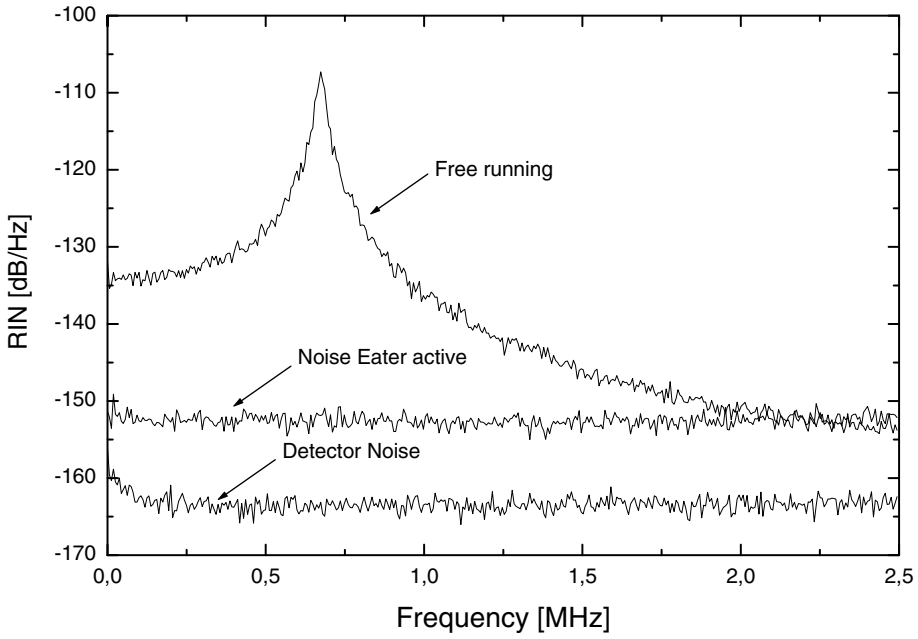


Figure 4.7: Relative Intensity Noise measurements of a **Mephisto** laser with and without Noise Eater option

Both these spectral components can be significantly reduced by using the *Noise Eater* option as illustrated by the trace "Noise Eater active" in Figure 4.7. To achieve this, a fraction of the generated Nd:YAG laser light, transmitted through a mirror, is focused onto a photo detector to analyze the variation of the generated output power. This signal, appropriately filtered and amplified by an electronic SMD board, is fed to the diode laser current to stabilize the output power.

Activating this feedback loop by the switch at the front panel of the control electronics unit (see Figure 2.2 and Figure 2.4), the Nd:YAG laser's intensity noise above a few 100 Hz is suppressed by up to 40 dB. The noise level is moved somewhat into the proximity of the quantum noise limit.

5 Standard Accessories

5.1 Laser Frequency Modulation

By applying an analog voltage signal in the range –10 V to +10 V to the modulation input labeled "Temperature Laser Crystal", using the BNC connector at the rear panel of the control electronics unit (see Figure 2.3 and Figure 2.5), the temperature of the laser crystal can be changed by +1 K / V, corresponding to a frequency change of about –3 GHz / V at 1064 nm. Due to the large time constants of the thermal tuning, the response bandwidth is limited to fractions of a Hertz.

5.2 Output Power Modulation

By applying an analog voltage signal in the range –10 V to +10 V to the modulation input labeled "Current Laser Diode", using the BNC connector at the rear panel of the control electronics unit (see Figure 2.3 and Figure 2.5), the injection current of the diode lasers used to pump the laser crystal can be modulated by 0.1 A / V. The response bandwidth of this modulation input is limited to about 5 kHz.

5.3 Temperature Guard

Failure to regulate the temperature of the diode lasers will result in diminished performance and lifetime. Hence, to ensure long term operation of the diode lasers, the **Mephisto** laser system is equipped with an integrated *Temperature Guard* that monitors deviations between the *Set temperature* and the *Actual temperature* of the *Laser Diode Driver*. It protects the laser diode against failure by switching the driver into inactive mode in case of any deviation between the two values for more than 1 minute. This is indicated by the *Guard* LED at the front panel of the Standard control electronics unit (see Figure 2.2) or the red *Error* LED at the front panel of the OEM control electronics unit (see Figure 2.4), respectively.

5.4 Safety Interlock

If your laboratory environment features an interlock switch that remains off under unsafe conditions, connect it to the left two pins of the three-pole screw-type connector at the rear of the unit. For activating the diode laser driver, these pins have to be shorted. The **Mephisto** laser system is shipped with a jumper installed. The present status of the *Interlock* is indicated by a yellow LED at the front panel of the Standard control electronics unit (see Figure 2.2) or the red *Error* LED at the front panel of the OEM control electronics unit (see Figure 2.4), respectively. If the *Safety Interlock* is activated, e.g. by disconnecting the two pins, the LED glows and the *Laser Diode Driver* will switch into inactive mode.

6 Pin Configurations

6.1 Laser Connector

The two units of the **Mephisto** laser system, the laser head and the control electronics unit, are to be connected only with a suitable cable, shipped with the laser system. The following Figure 6.1 illustrates the 37 pin D-Sub connector at the rear panel of both the Standard and OEM control electronics units:

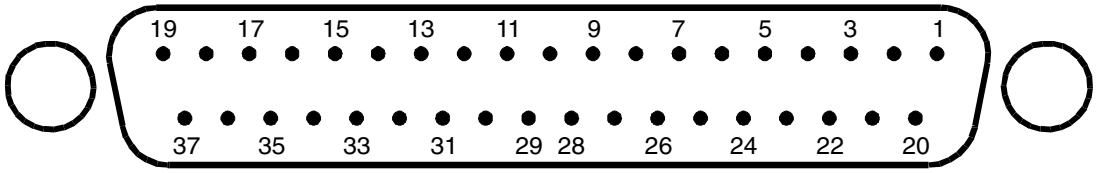


Figure 6.1: Laser connector (37 pin D-Sub) at the rear panel of the control electronics unit

The description of the individual pins of the laser connector is given in the following Table 6.1:

Pin	Description
1	Diode laser cathode
2	Diode laser 1, TEC anode
3	Diode laser 1, TEC cathode
4	Diode laser 2, TEC anode
5	Diode laser 2, TEC cathode
6	Laser crystal, TEC anode
7	Laser crystal, TEC cathode
8	n/c
9	n/c
10	Diode laser 1, monitor diode, cathode
11	Diode laser 1, monitor diode, anode
12	Laser crystal, NTC reference voltage 6,85 V
13	Laser crystal, NTC ground
14	n/c
15	Diode laser 1, NTC reference voltage 6,85 V
16	Diode laser 1, NTC ground
17	Diode laser 2, NTC ground
18	n/c
19	n/c
20	Diode laser anode
21	Supply voltage +12 V
22	Relay, negative supply voltage
23	GND
24	Relay, positive supply voltage
25	Supply voltage -12 V

Pin	Description
26	Noise Eater, monitor
27	Noise Eater, switch
28	n/c
29	Diode laser 2, monitor diode, cathode
30	Diode laser 2, monitor diode, anode
31	n/c
32	Interlock
33	GND
34	Diode laser 2, NTC reference voltage 6,85 V
35	n/c
36	n/c
37	n/c

Table 6.1: Pin description of the laser connector

6.2 Diagnostics Connector

All vital information about the status of the **Mephisto** laser system can be monitored without opening the control electronics unit, using the diagnostics connector. The following Figure 6.2 illustrates the 25 pin D-Sub connector at the rear panel of the Standard and OEM electronics units:

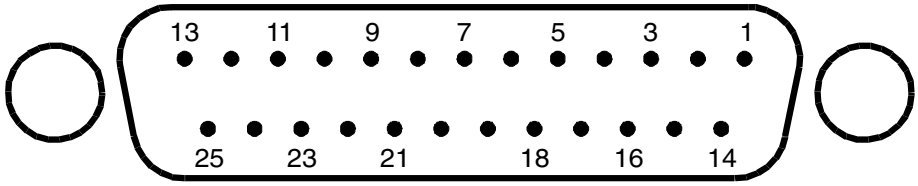


Figure 6.2: Diagnostics connector (25 pin D-Sub) at the rear panel of the control electronics unit

A description of the individual pins of the diagnostics connector for the **Standard** control electronics is given in Table 6.2:

Pin	Description
1	Diode laser 1, power monitor, 1 V / W
2	Diode laser 2, power monitor, 1 V / W
3	Laser crystal, TEC error signal, 10 V / °C
4	n/c
5	n/c
6	Diode laser 1, TEC error signal, 10 V / °C
7	Diode laser 2, TEC error signal, 10 V / °C
8	Diode laser 1, temperature guard
9	Diode laser 2, temperature guard
10	n/c
11	n/c
12	Noise Eater, monitor
13	Interlock
14-25	GND

Table 6.2: Pin description of the diagnostics connector of the **Standard** control electronics

The description of the individual pins of the diagnostics connector for the **OEM** control electronics is given in Table 6.3:

Pin	Description
1	Diode laser, current limit, 1 V / A
2	Diode laser, injection current, 1 V / A
3	Diode laser, set temperature, 10 mV / °C
4	Diode laser, actual temperature, 10 mV / °C
5	Diode laser, TEC error signal, 10 V / °C
6	Laser crystal, set temperature, 10 mV / °C
7	Laser crystal, actual temperature, 10 mV / °C
8	Laser crystal, TEC error signal, 10 V / °C
9	Error flag
10	Piezo monitor (Seeder option only), 10 mV / V
11	S & H voltage (Seeder option only), 1 V / V
12	Remote input (Seeder option only)
13	+12V / Monitor trigger (Seeder option only)
14-25	GND

Table 6.3: Pin description of the diagnostics connector of the **OEM** control electronics unit

6.3 Supply Voltage Indicators

In order to quickly check the presence of all supply voltages required for reliable operation of the **Mephisto** laser system without opening the control electronics unit, they are indicated by a set of 8 LEDs at the rear panel of the Standard control electronics unit (see Figure 2.3). The description of the indicators is given in the following Table 6.4:

LED	Description
L1	Negative supply voltage, temperature controllers
L2	Positive supply voltage, laser crystal temperature controller
L3	Positive supply voltage, diode laser 2 temperature controller
L4	Positive supply voltage, diode laser 1 temperature controller
L5	Supply voltage, diode lasers
L6	Supply voltage, noise eater
L7	Negative supply voltage, electronics
L8	Positive supply voltage, electronics

Table 6.4: Description of the supply voltage indicators at the rear panel of the control electronics unit

7 Warranty

InnoLight GmbH gives a 24 months warranty on its products, excluding the diode laser pump sources. The warranty period on the diode laser pump sources is 6 months. The warranty shall not cover any damage incurred during shipping. When the product is received by the customers, the shipping container and its content should be inspected for any damage incurred during shipping. In order to obtain service under this warranty, the customer must notify InnoLight GmbH of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. In all cases the customer will be responsible for properly packaging and shipping the product back to InnoLight GmbH, with shipping charges prepaid. If the product is not properly packed, it may be damaged in shipping and the warranty will be voided.

This warranty shall not apply to any defect, failure, or damage caused by improper use, failure to observe proper operating procedures per the product specifications (see section 3), or improper / inadequate maintenance. InnoLight GmbH shall not be obligated to furnish service under this warranty 1) to repair damage resulting from attempts by personnel (other than InnoLight GmbH's representatives) to repair or service the product; 2) to repair damage resulting from improper use or connection to incompatible equipment; 3) to repair damage resulting from operation outside of the operating environment specifications of the product; 4) to repair damage resulting from improper packaging of the product in order to return it to InnoLight GmbH.

Hannover, 10.10.2004

Version 4.6

InnoLight GmbH
Garbsener Landstr. 10
30419 Hannover
Germany
Tel.: +49 511 760 727-0
FAX: +49 511 760 727-99

Data Sheet and Test Report

DATA:

Model:	M2000NE LIGO				
Noise Eater Option:	Yes				
Serial No. Laser System:	1639C				
Serial No. NPRO Crystal:	Q122			T =	24.00 °C
Serial No. Diode A:	95021	I =	2.35 A	T =	21.90 °C
Serial No. Diode B:	88532	I =	2.35 A	T =	23.83 °C

TEST:

Output Power @ 1064 nm:	2.14 W
PZT tuning:	1.3 MHz/V
Electronics:	tested
sf-operation:	tested
Beam quality:	tested
Duration Test:	tested

Laser Tests:	**OK**
Date:	**12.11.2007**
Initials:	**MS**

LIGO Control Electonics Unit
Diagnostic Port I & II
Pin Configurations

Diagnostic port I Pin	*Description*	*Scaling*
1	Diode laser 1, power monitor	3V/W
2	Diode laser 2, power monitor	3V/W
3	Laser crystal, error signal	10V/K
4	n.c.	
5	n.c.	
6	Diode laser 1, temperature error signal	10V/K
7	Diode laser 2, temperature error signal	10V/K
8	Temperature guard: diode laser 2	-11V On; 11V Off
9	Temperature guard: diode laser 1	-11V On; 11V Off
10	n.c.	
11	n.c.	
12	Noise Eater, monitor	0.2V/mW (only linear at working point)
13	Interlock	12V On; 0V Off
14 - 25	GND	

Diagnostic port II pin	*Description*	*Scaling*
1	Diode laser 1, set temperature	0,2V/°C
2	Diode laser 1, act. temperature	(U-2V)/0.6 --> 0,2V/°C
3	Diode laser 2, set temperature	0,2V/°C
4	Diode laser 2, act. temperature	(U-2V)/0.6 --> 0,2V/°C
5	Laser crystal, set temperature	0,2V/°C
6	Laser crystal, act. temperature	0,2V/°C
7	Set Current	3V/A
8	Act. Current	3V/A
9	Status Laser ON	5V ON, 0V OFF
10	n.c.	
11	Remote SW	
12	Remote SW ON	
13	Remote SW OFF	
14 - 25	GND	

Remote control:

Laser on: connect PIN 11 with PIN 12 just for a short periode of time.

Laser off: connect PIN 11 with PIN 13 just for a short periode of time.

OPHIR
Laser Measurement Group

Certificate Of Calibration

OPHIR OPTRONICS HEREBY CERTIFIES THAT THIS INSTRUMENT MEETS ALL CURRENT PUBLISHED SPECIFICATIONS AND HAS BEEN CALIBRATED USING STANDARDS TRACEABLE TO THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) OR OTHER STANDARDS ACCEPTED BY NIST IN ACCORDANCE WITH **ISO 10012-1**

Issued To: _____
Certificate No: 239031-001 **Serial No:** 239031
Model Name: NOVA II **Catalog No:** 1Z01550

CALIBRATION STANDARDS TRACEABILITY DATA

Manufacturer	Model	Serial #	Test #	Uncertainty	Last Cal Date	Next Cal Due
FLUKE	8842A	KM2768	8612334599	0.1%	7/2006	7/2007

Note: Instrument calibration is performed using an automated current calibration unit. This calibration unit is periodically calibrated against the Fluke Voltmeter which is traceably calibrated.

Performed By: Alon Eliyaho
Reviewed By: Adi Levi **Date:** 13-DEC-2006 **Signed:** _____

OPHIR Q.C 12 CERTIFIED QMS SI ISO 9001: 2000

Next Calibration Due: JUN 2008

Ophir Optronics Calibration Centers:

USA: Tel: +1-978-657-5553 Fax +1-978-657-6054 Email: service@ophiropt.com
Japan: Tel: +81-48-646-4150 Fax: +81-48-646-4155 Email: info@ophirjapan.co.jp
Europe: Tel: +49-89-890-1350 Fax: +49-89-800-2561 Email: service.de@bfioptilas.com
Israel: Tel +972-2-548-4481 Fax: +972-2-582-2338 Email: customer.support@ophiropt.co.il

WWW.OPHIROPT.COM

OPHIR
Laser Measurement Group

Certificate Of Calibration

OPHIR OPTRONICS HEREBY CERTIFIES THAT THIS INSTRUMENT MEETS ALL CURRENT PUBLISHED SPECIFICATIONS AND HAS BEEN CALIBRATED USING STANDARDS TRACEABLE TO THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) OR OTHER STANDARDS ACCEPTED BY NIST IN ACCORDANCE WITH **ISO 10012-1**

Issued To: _____
Certificate No: 520772-001 **Serial No:** 520772
Model Name: 150W-SH **Catalog No:** 171001

CALIBRATION DATA

Wavelength Range	Calibration Wavelength	Sensitivity	Accuracy
CO2	10600nm	28.382nA/W	See datasheet *
YAG	1064nm	26.610nA/W	See datasheet *
VIS	532nm	27.059nA/W	See datasheet *

* Data sheets are enclosed for new heads. For heads sent for recalibration or repair, please refer to the data sheets that were originally sent with the heads

CALIBRATION STANDARDS TRACEABILITY DATA

This head has been calibrated using one or more of the following standards:

Manufacturer	Model	Serial #	Test #	Uncertainty	Last Cal Date	Next Cal Due
OPHIR, NIST CAL	30A-SH	KM3468	814736	1.2%	2/2007	2/2008
OPHIR, NIST CAL	FL250A-SH	KM3487	814759/814760	1.2%	5/2007	5/2009
OPHIR, NIST CAL	PD300-IR-SH	KM3476	844/274518-07	1.4%	4/2007	4/2009
OPHIR, NIST CAL	PD300-UV-SH	KM3471	844/274194-07	0.4%,400-950nm 1.5%,200-400nm 2.2%,950-1064nm	4/2007	4/2009
OPHIR,NIST CAL	3A-P-SH-V1	KM3488	814757	1.2%	5/2007	5/2008
Labsphere NIST	SRS-99-010	50839-1-1	50839-1-1	0.5% 250 -2500nm	12/2006	12/2007
Ocean Optics NIST	STAN-SSH-NIST	0070	CERT 0078	1.0% 200 - 400nm 0.5% 400 - 2200nm	2/2006	2/2008

Performed By: Motti Cohen
Reviewed By: Moshe Ohayon **Date:** 13-DEC-2007 **Signed:**

Next Calibration Due: JUN 2009

Ophir Optronics Calibration Centers:

USA: Tel: +1-435-753-3729 Fax +1-435-753-5231 Email: service@ophir-spiricon.com
Japan: Tel: +81-48-646-4150 Fax: +81-48-646-4155 Email: info@ophirjapan.co.jp
Europe: Tel: +49-89-890-1350 Fax: +49-89-800-2561 Email: service.de@bfioptilas.com
Israel: Tel +972-2-548-4481 Fax: +972-2-582-2338 Email: customer.support@ophiropt.co.il

www.ophiropt.com

Model Series 400X
User's Manual

DC-100 MHz Electro-Optic Phase Modulators

【ν】

Warranty

New Focus, Inc. guarantees its products to be free of defects for one year from the date of shipment. This is in lieu of all other guarantees, expressed or implied, and does not cover incidental or consequential loss.

Contents

Introduction

The New Focus model 400X series of electro-optic phase modulators provides an efficient means for optical phase modulation in the DC to 100 MHz frequency range. These versatile phase modulators can be operated with low to moderate drive voltages, and their 2-mm apertures make them compatible with most laser sources. Other features of these devices include their high modulation frequency, low insertion loss, good RF shielding, and high optical-power handling capability.

The model 400X series consists of four modulators classified according to operating wavelengths and electronic drive requirements. The operating wavelengths are determined by the anti-reflection coating applied to the surfaces of the electro-optic crystals. Two standard wavelength ranges are offered: 0.45-0.85 µm and 1.0-1.6 µm. Regarding electronic drive requirements, the following two types of modulators are offered:

1. **Models 4002 and 4004 Broadband Phase Modulators** can be operated at any frequency from DC to 100 MHz and require on the order of 210 volts to achieve a π phase shift.

2. **Models 4001 and 4003 Resonant Phase Modulators** operate at a single user-specified frequency anywhere in the range 0.01 to 100 MHz. These devices can only be operated at their resonant frequency but require much lower drive voltages—on the order of 16 volts to achieve a π phase shift.

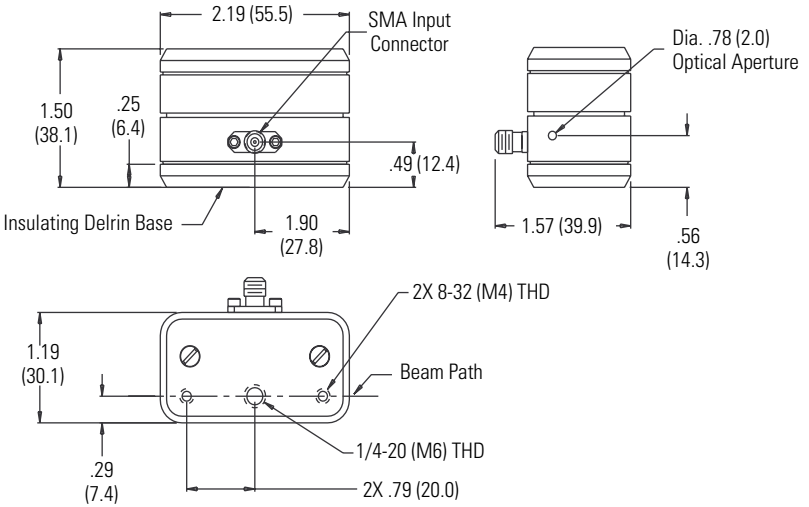
The broadband phase modulators are appropriate for applications where modulation over a broad frequency range is required. For applications requiring phase modulation at a single frequency, the resonant phase modulators are preferred because much higher phase shifts can be achieved with a given drive voltage.

All of these devices employ electro-optic crystals where an applied electric field induces a change in the crystal's refractive index. The Model 400X series phase modulators use lithium tantalate ($LiTaO_3$) and lithium niobate ($LiNbO_3$) crystals as the electro-optic medium. Magnesium-oxide-doped lithium niobate ($MgO:LiNbO_3$) crystals are also available for higher optical-power handling capability. All of these materials are nonhygroscopic, and so, they can be left on an optical table for indefinite periods without requiring a sealed enclosure.

Table 1 (page 15) is the product matrix for the 400X series phase modulators and lists the physical characteristics and performance specifications for these modulators. A mechanical drawing of the 400X modulator is shown in Figure 1 (page 6).

Fig. 1

Mechanical views of the model 400X electro-optic modulator.



Principles of Operation

Operation of New Focus electro-optic phase modulators is based on the linear electro-optic (or Pockels) effect —the linear dependence of the refractive index on the applied electric field. The effect of an applied electric field on a crystal's refractive index is described by a third-rank tensor r_{ij}. The induced refractive index change caused by an external electric field has the form

$$\Delta n = \frac{1}{2} n_e^3 r_{33} E \ ,$$

where Δn is the change in the index of refraction, n_e is the unperturbed index of refraction, r_{33} is the appropriate element in the electro-optic tensor, and E is the applied electric field. $LiNbO_3$ and $LiTaO_3$ are attractive crystals for use in these types of modulators because they have wide spectral transparency windows, large r coefficients, and low RF losses.

The New Focus phase modulators consist of an electro-optic crystal of length l with electrodes separated by the crystal thickness d. The electric field is applied along a crystal axis and transverse to the direction of optical propagation. Modulation is induced onto the laser beam by aligning the polarization of the input beam with the crystal axis along which the electric field is applied. An electronic signal is then directly modulated onto the laser beam through the electro-optic effect.

For the models 4002 and 4004 broadband phase modulators, the input electronic signal is applied directly across the crystal's electrodes. So, the optical phase shift obtained by applying a voltage V at the input SMA connector is

$$\Delta\phi = \frac{2\pi}{\lambda}\left(\frac{1}{2}n_e^3 r_{33}\right)\frac{l}{d}V ,$$

where λ is the free-space wavelength. A commonly used figure of merit for electro-optic modulators is the half-wave voltage, V_π, which is defined as the voltage required to produce a phase shift of 180°. Substituting into the preceding equation yields

$$V_\pi = \frac{\lambda d}{n_e^3 r_{33} l} .$$

For the broadband phase modulators, V_π is typically 210 volts at 1.06 µm, corresponding to a modulation depth, β, of 0.015 radians/volt. Note that at other wavelengths these values change proportionately. So, at 532 nm V_π is 105 volts, and β is 0.03 radians/volt.

For the models 4001 and 4003 resonant phase modulators, the crystal is combined with an inductor to form a resonant tank circuit. On resonance, the circuit looks like a resistor whose value depends on the inductor's losses. A transformer is used to match this resistance to the 50-Ω driving impedance. Putting the crystal in this resonant circuit results in a voltage across the crystal electrodes that can be more than ten times the input voltage across the SMA connector. This leads to reduced half-wave voltages and larger modulation depths when compared to the broadband modulators.

For the resonant phase modulators, the peak phase shift obtained by applying a sinusoidal signal of average power P at the input SMA connector is

$$\Delta\phi = \frac{2\pi}{\lambda}\left(\frac{1}{2}n_e^3 r_{33}\right)\frac{l}{d}\sqrt{2PQ\sqrt{\frac{L}{C}}},$$

where Q is the quality factor of the tank circuit, L is the inductance, and C is the crystal capacitance. For the resonant phase modulators V_π is typically 16 volts at 1.06 µm, corresponding to a modulation depth β of 0.2 radians/volt.

A sinusoidal waveform applied to the modulator will produce frequency sidebands which are separated from the optical carrier by the modulation frequency. These modulation sidebands can be observed by looking at the beam with an optical spectrum analyzer. Given an induced peak optical phase shift of $\Delta\phi$ (in radians), the fraction of power transferred to each of the first-order sidebands is $[J_1(\Delta\phi)]^2$, where J_1 is the Bessel function of order 1. The fraction of power that remains in the carrier is $[J_0(\Delta\phi)]^2$, where J_0 is the Bessel function of order 0.

For example, imposing a sinusoidal phase shift of peak amplitude 1 radian to a cw laser beam will transfer 19% of the initial carrier power to each of the first-order sidebands and leave 59% of the power in the carrier. Note that the maximum power that can be transferred to the first-order sidebands is about 34%, and this requires a peak phase shift of 1.8 radians. For the broadband phase modulator, at 1.06 µm a 1.8 radian phase shift is achieved with about 120 volts. For the resonant phase modulator, a 1.8 radian phase shift requires an input peak voltage of about 9 volts (0.81 W average power).

Operation

When used properly, the 400X series phase modulators can provide efficient phase modulation with extremely low unwanted amplitude modulation and insertion loss. The key to obtaining this pure phase modulation is good optical alignment of the beam to the crystal's propagation axis, and accurate polarization orientation of the laser's electric field with the crystal's electro-optically active axis.

To align the module to the optical beam:

1. Use the 1/4-20 (M6 for metric versions) tapped hole located on the base of the module to mount it on an adjustment-positioning device for alignment. We recommend the New Focus Model 9071 or 9071M tilt aligner because of its tilt and translation capabilities.

2. Turn on the optical beam, and orient the beam so it is vertically polarized on the input aperture (see Fig. 2). It is important to carefully align the polarization since the crystals used by New Focus are cut so that the beam propagates along the y-axis of the crystal. This orientation minimizes the effects of acoustic resonances but makes it critical that the optical beam be linearly polarized vertically along the z-axis. If the polarization of the optical beam is not properly aligned, the modulators will impose a polarization rotation as well as a phase modulation which can lead to unwanted amplitude modulation if the modulator is followed by any polarizing optics.

3. Position and align the module so that the beam passes through the 2-mm input and output apertures, clearing them without clipping. The beam

to be modulated should be collimated with a waste size of less than 2 mm, and such that the Rayleigh range is at least the length of the crystal. To avoid damage resulting from excessive optical intensity, the optical power should be kept below the damage thresholds listed in Table 1. Typically, a good beam size is 250–500 µm.

To set up the electrical modulating input signal:

Using an SMA cable, connect the SMA jack on the modulator to a modulating source appropriate for the type of modulator (resonant or broadband) you are using.

NOTE: Since the optical alignment of the modulator can be disturbed by the SMA cable, ensure that the SMA orientation is not obstructing the alignment and use a strain relief on the cable.

The models 4001 and 4003 resonant modulators are tuned to a specific frequency and require very low drive voltages, such as that from a simple crystal oscillator or a function generator that has an output impedance near 50 Ω. The reflected power from resonant phase modulators at their specified resonant frequency is very low compared to broadband modulators.

The models 4002 and 4004 broadband modulators require large drive voltages and have a bandwidth dependent on the impedance of the modulating source. With a 50-Ω source, the bandwidth will be approximately 100 MHz. The source must be able to drive an open circuit without causing damage to the source. We recommend a New Focus Model 3211 high-voltage amplifier for operation at frequencies from DC to 600 kHz.

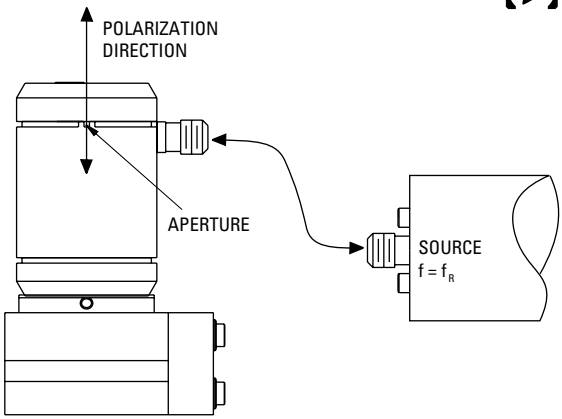


Fig. 2. A phase modulator being driven by a source tuned to f_R. The module is mounted on a Model 9071 tilt aligner. The input beam is vertically polarized.

A note about optical damage:

The electro-optic crystals used in these modulators are susceptible to optical damage through the photorefractive effect. Photorefractive damage becomes more of a problem for high optical powers, short wavelengths, and tightly focused beams. Table 1 (page 15) lists maximum average power levels above which optical damage will occur. New Focus also offers modulators with MgO-doped $LiNbO_3$ crystals which have higher damage thresholds.

The photorefractive damage process can occur gradually over days or hours, or, for high optical powers and short wavelengths, this effect can occur over seconds. A damaged crystal will distort a beam, usually by elongating it in the vertical direction. If operating close to the damage threshold, it is a good idea to monitor the transmitted beam periodically for indications of optical damage. Photorefractive damage can be partially reversed by carefully annealing the crystal; please contact New Focus for details on this procedure.

Specifications

1. Optical Throughput

Optical throughput is determined by the absorption and scatter in the electro-optic crystal, and by the quality of the anti-reflection coatings on the end faces. Low optical losses are critical in applications of the New Focus phase modulators, so great care is taken to ensure insertion loss is minimized.

2. Modulation Depth

This describes the magnitude of the phase modulation imposed on the input laser beam by the modulator. This depth is optimized by alignment of the input beam's polarization with the crystal active axis.

3. Residual Amplitude Modulation (RAM)

RAM is noise in a phase modulation system, and therefore must be minimized. Quality of crystal growth and excellence in the finished crystal design and manufacturing are essential to the elimination of RAM. Experimentally, precise alignment is required to prevent RAM from occurring.

4. Return Loss

The return loss indicates the quality of impedance matching between the driving source and a resonant phase modulator. Resonant modulators are designed to have impedances very close to 50 Ω at resonance, and a high return loss indicates a good impedance match between the driving source and the modulator. With a high return loss, power transfer to the modulator is

optimized, and reflected power, which can harm RF drivers, is minimized.

The return loss indicates the fraction of RF power reflected from the modulator back to the driver when the modulator is driven at its resonant frequency. For a power reflection coefficient R, the return loss in dB is $-10 \log R$. All New Focus resonant phase modulators are tested by measuring return loss versus frequency around the modulation frequency. The results of this test are provided at the rear of this manual.

5. Voltage Standing Wave Ratio (VSWR)

VSWR, like return loss, is another way to specify the quality of impedance matching between RF driver and resonant modulator. It is defined as the voltage ratio between the maximum and minimum of the standing wave that occurs because of an impedance mismatch. A VSWR value of 1 indicates a perfectly matched system. Given a return loss RL (in dB), the VSWR can be found from

$$VSWR = \frac{1+10^{-RL/20}}{1-10^{-RL/20}}.$$

Table 1

Specifications for the 400X Series electro-optic phase modulators.

Model #	4001, 4003	4002, 4004
Wavelength	0.45–0.85 µm (4001) 1.0–1.6 µm (4003)	0.45–0.85 µm (4002) 1.0–1.6 µm (4004)
Type	Resonant PM	Broadband PM
Operating Freq.	0.01–100 MHz	DC–100 MHz
RF Bandwidth	1–2% freq.	100 MHz
Material	$LiTaO_3$ or $MgO:LiNbO_3$	$LiTaO_3$ or $MgO:LiNbO_3$
Max. Optical Power*	200 mW/mm^2 (633 nm) 1 W/mm^2 (1.3 µm)	200 mW/mm^2 (633 nm) 1 W/mm^2 (1.3 µm)
Max. Optical Power* ($MgO:LiNbO_3$)	5 W/mm^2 (647 nm)	5 W/mm^2 (647 nm)
Aperture	2 mm	2 mm
Optical Throughput	>93%	>93%
Residual AM†	-60 dB	-60 dB
Connector	SMA	SMA
Impedance	50 Ω	20–30 pF
Max. RF Power	1 W	-NA-
Modulation Depth (at 1.06 µm)	>0.2 rad/V	15 mrad/V
Max V_π (1.06 µm)	16 V	210 V
Return Loss	>14 dB	-NA-
VSWR	<1.5	-NA-

* In a 1 mm beam.

† RAM measured with a 1 rad phase modulation.

Performance Data

Model Number: _____

Serial Number: _____

Frequency: _____

Wavelength: _____

Input RF Power: _____

Return Loss: _____

VSWR: _____

Q: _____

New Focus, Inc.
2630 Walsh Ave.
Santa Clara, CA 95051-0905
(408) 980-8088 • (408) 980-8883
E-mail: Contact@NewFocus.com

AO MODULATOR DATA SHEET

Model 3080-194

Part Number: 97-02814-01 Rev: B

Work Order: 801804

Serial Number: 13825 Cell: AXX -

Date: 5/10/2007

Measured Performance at Wavelength 1064 nm
Beam Diameter 1100 µm; RF Power 2.50 W

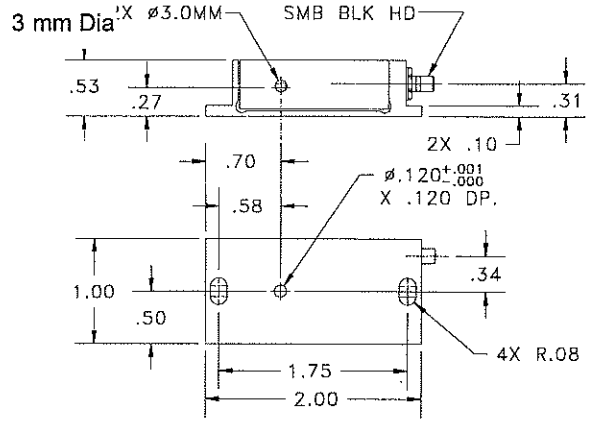
Test	Min Spec.	Meas.	Max Spec.
Insertion Efficiency (%)	96	99.2	
Diffraction Efficiency (%)	80	85.4	
Contrast Ratio	1000 :1	3277	
VSWR at 80 MHz		1.01 :1	1.3 :1

DEVICE CHARACTERISTICS:

Polarization	90 ° To Mounting Base
Bragg Angle	10.1 mr
Beam Separation	20.2 mr

Center Frequency: 80 MHz Bandwidth: 10 MHz

Package Drawing



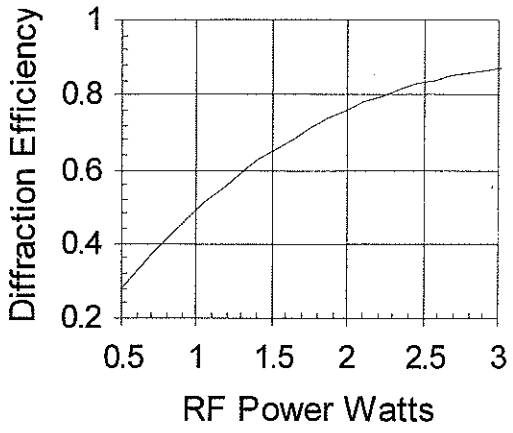
Theoretical Data Curves

Actual Devices May Vary

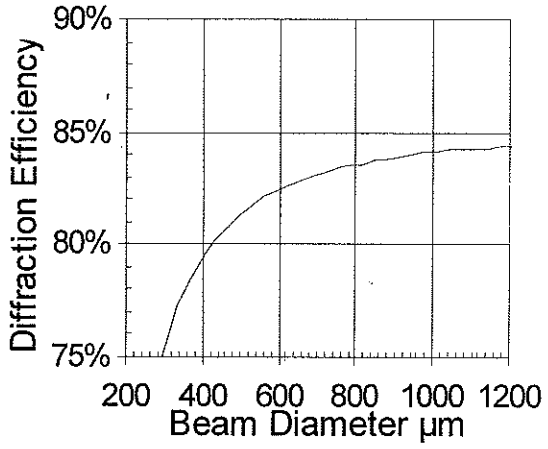
1.064

Diffraction Efficiency vs RF POWER

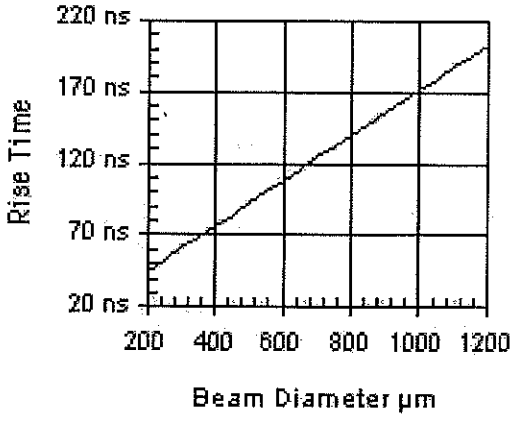
Beam Diameter 1100 µm



Diffraction Efficiency vs Beam Diameter



Rise Time vs Beam Diameter



Crystal Technology, Inc.
A Siemens Company

t Meadow Circle
California 94303
(650) 856-7911
(650) 354-0173

OPTICAL ISOLATOR PERFORMANCE REPORT

IO-λ Optical Isolator

Model #: IO-8-1064-I

(Body Type IX)

Customer:	LASER 2000 GmbH	**Date Tested:**	05-03-07
PO No.:	2711246	**Sales Order No.:**	32401
Model:	IO-8-1064-I	**Serial No.:**	32401-1-1

Wavelength:	1064 nm	**Power:**	1351 uW	**Temp:**	22 deg. C
Rotator Transmission:	98.6 %		**Faraday Rotation:**		45 Degrees
Isolator Transmission:	%				
Isolation:	dB				

Notes: I = NO POLARIZERS EXTINCTION = 40.4 dB

JB
Inspector's Signature

5/3/07
Date Tested

CAREFUL

Do not attempt to disassemble the isolator.

The IO-λ series isolator contains a powerful permanent magnet. Keep all steel objects and anything affected by a magnetic field at a minimum distance of 2" (50 mm) from the isolator.

The isolator magnet must remain contained by the isolator body. The polarizer cells can be safely removed from the rest of the isolator. However, any other disassembly of the isolator voids the warranty and can be unsafe.

OFR 62 Depot St. Verona, NJ 07006 * Phone: 973-228-4480 * Fax: 973-228-0915 * info@ofr.com

OFR
62 Depot Street
Verona New Jersey 07044

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Fax: (973) 228-0915
Email: info@ofr.com

Owner's Instructions
IO-λ Series Optical Isolator
(Body Type IX)

CAREFUL

The **IO-λ series isolator** contains a powerful permanent magnet. Keep all steel objects and anything affected by a magnetic field at a minimum distance of 2" (50 mm) from the isolator.

Do not attempt to disassemble the isolator. The isolator magnet must remain contained by the isolator body. The polarizer cells can be safely removed from the rest of the isolator. However, any other disassembly of the isolator voids the warranty **and can be unsafe.**

WARRANTY

Your **IO-λ series isolator** is covered by OFR's six-month warranty against defects in materials and workmanship. **Do not attempt to disassemble the isolator.** Disassembly of the isolator voids the warranty **and can be unsafe.**

OFR 5/2006

DIAGRAM AND NOTES:
IO-λ SERIES, BODY TYPE IX

An isolator consists of a Faraday rotator and at least two polarizers.

The gold and black central cylinder is the **Faraday rotator case.**

The two 1" black cylinders are the **polarizer cells.** The cell's scribe lines indicate the axis of polarization. These should line up approximately with the scribe lines on the black barrel endcaps. The side escape ports (PBS, HP, and VHP types only) are for any rejected beams.

The isolator is mounted on a black **saddle,** which has English and metric bores for post-mounting.

The **part number** consists of:

- **"IO"** (the OFR isolator code);
- the **aperture** in mm (approx.);
- the **center wavelength** in nm;
- and the **polarizer type.**

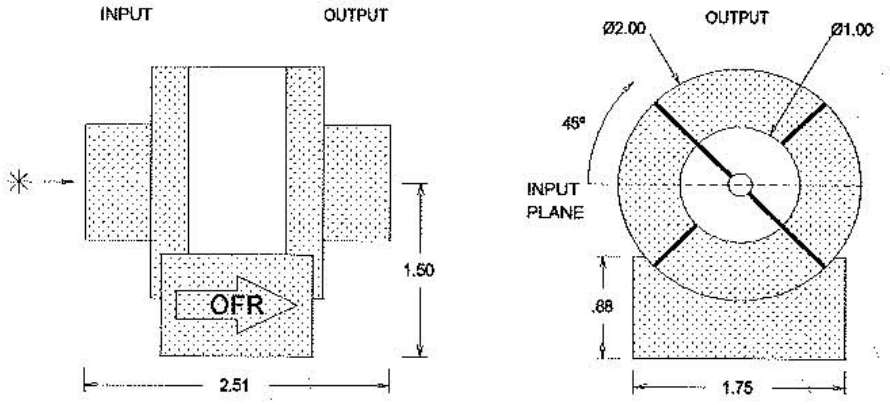
Example: *an IO-5-1064-HP has a ~5 mm aperture, a 1064 nm center wavelength, and HP polarizers.*

All **Body Type IX** isolators have similar dimensions. Their overall lengths vary (see table); however, the other key dimensions are as shown in the diagrams. For further details, discuss with OFR.

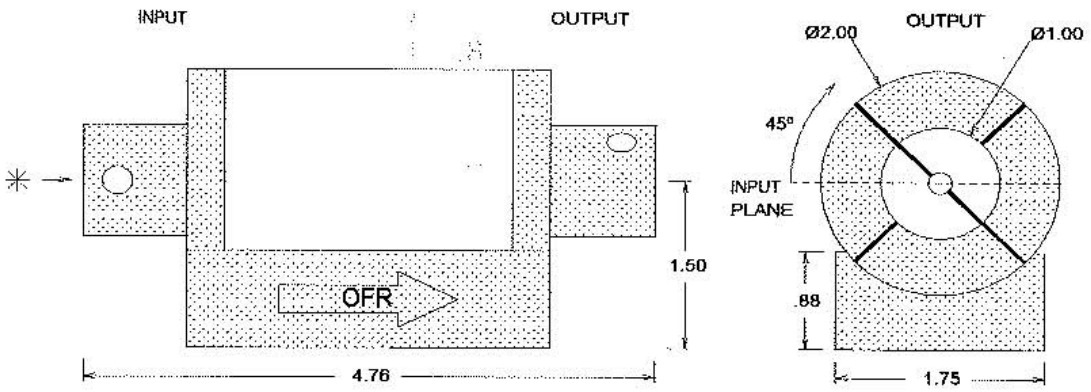
IO-5-λ-LP *(λ=505-700)*	2.51"
IO-5-λ-LP *(λ=760-830)*	3.58"
IO-5-λ-LP *(λ=380-505)* **IO-5-λ-LP** *(λ=830-925)*	4.11"
IO-5-λ-HP *(λ=505-700)*	3.16"
IO-5-λ-HP *(λ=760-830)*	4.23"
IO-5-λ-HP *(λ=415-505)* **IO-5-λ-HP** *(λ=830-1100)*	4.76"
IO-5-532-VHP	3.45"
IO-5-λ-VHP *(λ=488, 1064)*	5.05"

See the OFR catalog or web site for a fuller list of Body Type IX isolators.

IO-5-633-LP Optical Isolator (Typical Body Type IX LP Isolator)



IO-5-1064-HP Optical Isolator (Typical Body Type IX HP Isolator)



HOW THE ISOLATOR WORKS

OFR isolators are used to reduce or eliminate the effects of optical feedback - reflections of the laser's energy back into itself. These effects include noise, amplitude fluctuation, and even laser damage.

OFR isolators protect the laser, while maintaining beam alignment and providing maximum forward transmission and reverse isolation.

An isolator consists of a Faraday rotator, two polarizers and a housing. The Faraday rotator consists of a magneto-optic material within a magnetic field.

Operation

The forward mode: Laser light enters the isolator via the input polarizer and is linearly polarized. It then enters the rotator, which rotates its plane of polarization 45°. It then exits via the output polarizer, whose axis is 45° from the input plane of polarization.

The reverse mode: Some random beam reflections will be reflected back towards the laser. This feedback re-enters the isolator via the output polarizer and is polarized at 45°. It continues into the rotator and is rotated by another 45°. The feedback, now polarized at 90° relative to the input polarizer, is extinguished.

The laser is now isolated from its own reflections.

USING THE ISOLATOR

Notes: *OFR aligns the isolator for horizontal input polarization unless the customer requests otherwise.*

If you have an "LP" model, do not place the isolator < 6" from the laser - LP polarizers reject at 7° from the passing beam, and the rejected feedback can strike a close laser.

Initial alignment:

1. Remove the protective tape from the polarizer cells.
2. Place the isolator in the laser beam. Place a detector > 8" from the output polarizer. Center the beam.
3. Loosen the set screws holding the polarizer cells.
4. Rotate the input polarizer until transmission is maximized, thus aligning it to the laser's plane of polarization. Lock down its set screw.
5. Rotate the output polarizer until transmission is maximized. This occurs nominally at 45° cw* relative to the input plane of polarization.

Fine tuning to optimize isolation:

6. Reverse the isolator, so the output polarizer faces the laser and the detector is a few inches from the input polarizer. Center the beam.
7. Adjust the output polarizer (now facing the laser) by 1-2° until transmission is minimized. Lock down its set screw.
8. Return the isolator to the operating position. Center the beam.
9. The isolator is now aligned and ready for use.

** viewed facing the laser – see diagram*

OPTIMUM PERFORMANCE GUIDELINES:

Wavelength: **IO-λ series isolators** can be tuned for use near the central wavelength.

OFR sets the isolator for maximum isolation at a center wavelength. If the laser deviates from this wavelength, rotation is no longer the ideal 45° and isolation decreases. However, within ± 5% of the central wavelength, the isolator can be tuned to maintain full isolation and near-optimal (97% of peak) transmission.

Example: *An isolator centered at 815 nm rotates 45°. If its isolation and transmission are 40 dB and 94%, what are these values when retuned for full isolation at 780 nm?*

Over a small wavelength range, rotation is proportional to $1/\lambda^2$. *Therefore, rotation at 780 nm is ~49°. However, if the output polarizer is set at 49°, any feedback will be at 98° with respect to the input polarization plane. Isolation will decrease. But if the output polarizer is set at 41° (90°-49°), the feedback will be at 90°. Isolation will remain 40 dB.*

Finally, the Law of Malus shows that transmittance through two polarizers is proportional to the $\cos^2$ *of the angle between their polarization planes. This angle is 8° (49°-41°), so the* $\cos^2$ *is 0.98. Thus, transmission is reduced by 2%, from 94% to 92%.*

Output polarization: **IO-λ series isolators** have an output polarization of ~45° relative to that of the input. If another polarization plane is desired (usually horizontal or vertical), **½-wave retarders** are available. These retarders, mounted in snap-on cells which fit over the output polarizer cell, can rotate the output polarization to any desired linear orientation.

Temperature: A change in temperature, like a change in wavelength, affects rotation. If you plan to use your isolator at other than the test temperature, discuss with OFR.

Laser Power: The safe power limit for a Body Type IX isolator depends on its polarizers. See below for the **polarizer options** OFR offers for these isolators.

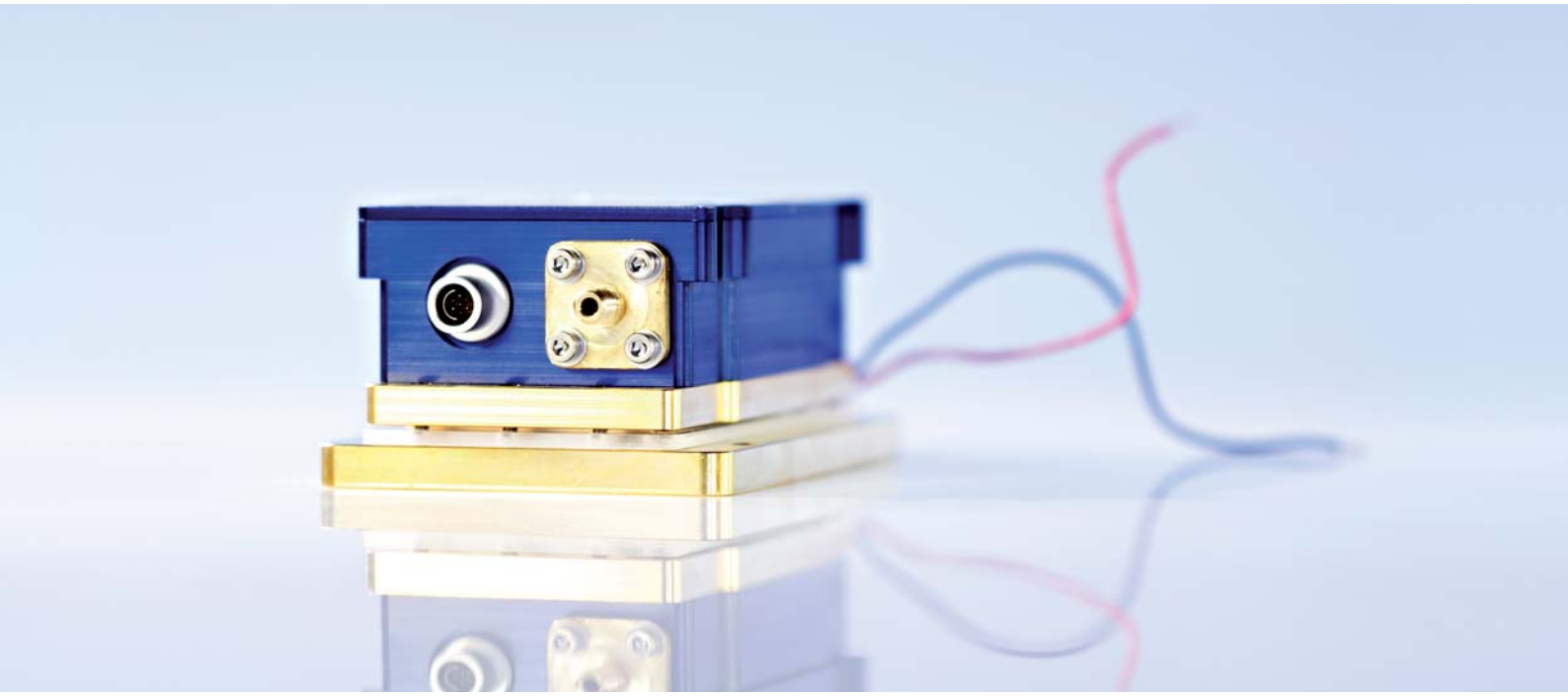
Model	Type of Polarizer	CW power max	Pulsed power max*
VLP	Thin Plate	25 W/cm^2	300 kW/cm^2
PBS	Polarizing B/S Cube	13 W/cm^2	-----
LP	Air-spaced Calcite	100 W/cm^2	25 MW/cm^2
HP	Air-spaced Calcite	500 W/cm^2	150 MW/cm^2
VHP	Brewster's Angle Plate	20 kW/cm^2	1 GW/cm^2
* Pulsed measurements made at 1064 nm, 20 ns pulse width, 20 Hz.			

JENOPTIK
GERMANY

Fiber-Coupled Passively Cooled cw Diode Lasers

JOLD-45-CPXF-1L

Design 15415624 / 15415124



Features:

- High optical output power of 45 W cw
- Fiber core diameter: 400 µm / 600 µm (NA 0.22)
- Long lifetime > 20,000 h, high reliability
- Passively cooling with integrated TECs

LongLife Technology®

Applications:

- Pumping of solid-state lasers and fiber lasers
- Material processing in industry
- Medical applications

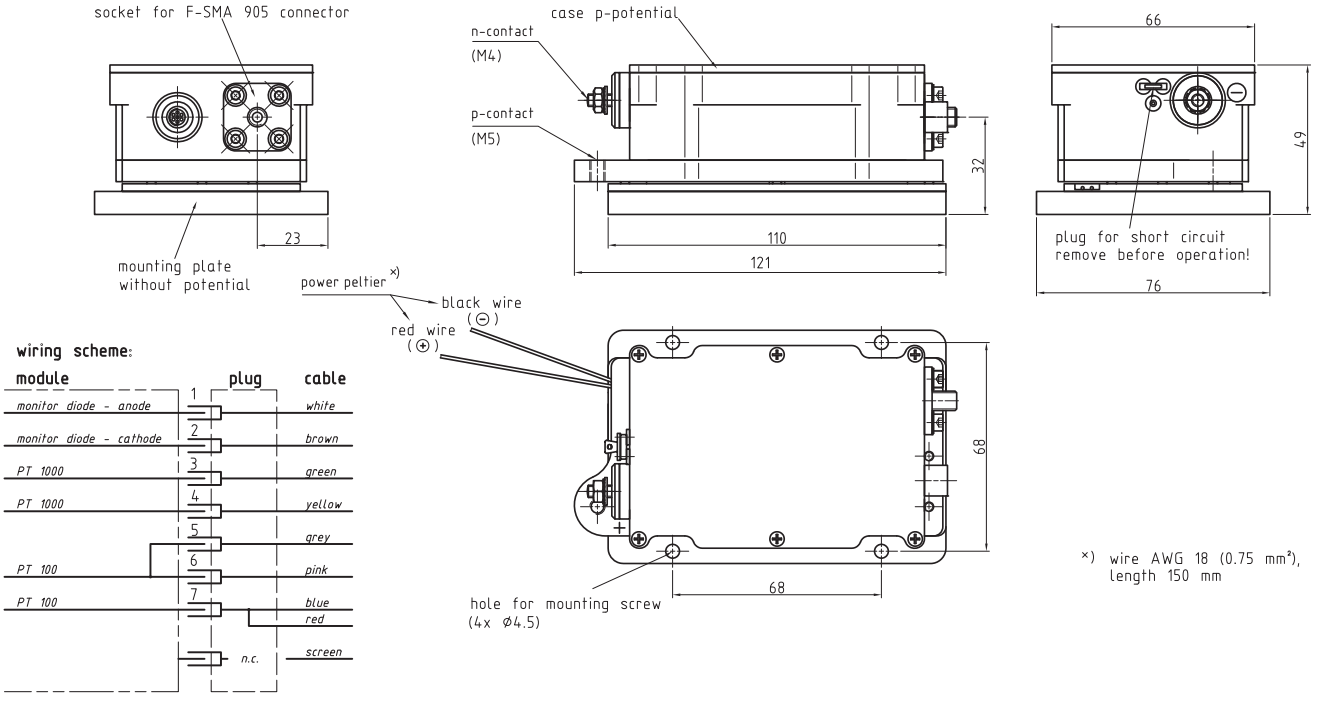
Diode Laser Group

Fiber-Coupled Passively Cooled cw Diode Lasers

Preliminary Specifications (Start of Life)

Product	JOLD-45-CPXF-1L, Design 15415624 / 15415124				
Operation Mode	cw, power modulation only between threshold and maximum current				
Maximum Optical Output Power	45	45	45	45	W
Center Wavelength at 25 °C	808	915	938	976	nm
Center Wavelength Variation at 25 °C	3	5	5	3	nm
Typical Spectral Bandwidth (FWHM)	3	3	3	3	nm
Maximum Spectral Bandwidth (FWHM)	4	4	4	4	nm
Typical Operation Current	59	60	60	64	A
Maximum Operation Current	65	66	66	70	A
Typical Threshold Current	10	6	6	6	A
Maximum Threshold Current	13	9	9	9	A
Typical Slope	1.0	0.9	0.9	0.8	W/A
Minimum Slope	0.8	0.7	0.7	0.7	W/A
Maximum Operating Voltage	2	2	2	2	V
Fiber Core Diameter, Numerical Aperture	**Design 15415624:** 400 µm, NA 0.22 **Design 15415124:** 600 µm, NA 0.22				
Fiber Connector	F-SMA 905 (for design 15415624: with free standing fiber end towards the module)				
Power Monitor	Infineon, SFH 229				
Anode, Cathode Connectors	M5 (socket cap screw DIN 912), M4 (threaded bolt and hex nut DIN 934)				
Operation Conditions	Non-condensing atmosphere				
Expected Lifetime	> 20,000 h (constant current), under qualification				
Cooling:					
Mounting	Via thermally conductive foil (thickness 25 ... 100 µm) on cooled surface				
Note	**Do not mount via any paste-like media!**				
Diode Laser Operating Temperature	15 ... 30 °C, measured with internal temperature sensor				
Temperature Sensor	PT 100 and PT 1000				
Integrated TECs	Connected in series, cold side at max. 30 °C				
Maximum Cooling Power	2 TECs x 173 W => 346 W				
Maximum TEC Voltage, Current	2 x 24.6 V => 49.2 V, 11.3 A				
	Manufactured under license of FhG-ILT Aachen (Germany).				
	See General User Information!				

Options on request: 30 W cw (JOLD-30-CPXF-1L); 70 W qcw (JOLD-70-QPXF-1L, design 15415124); 981 nm



x) wire AWG 18 (0.75 mm²), length 150 mm

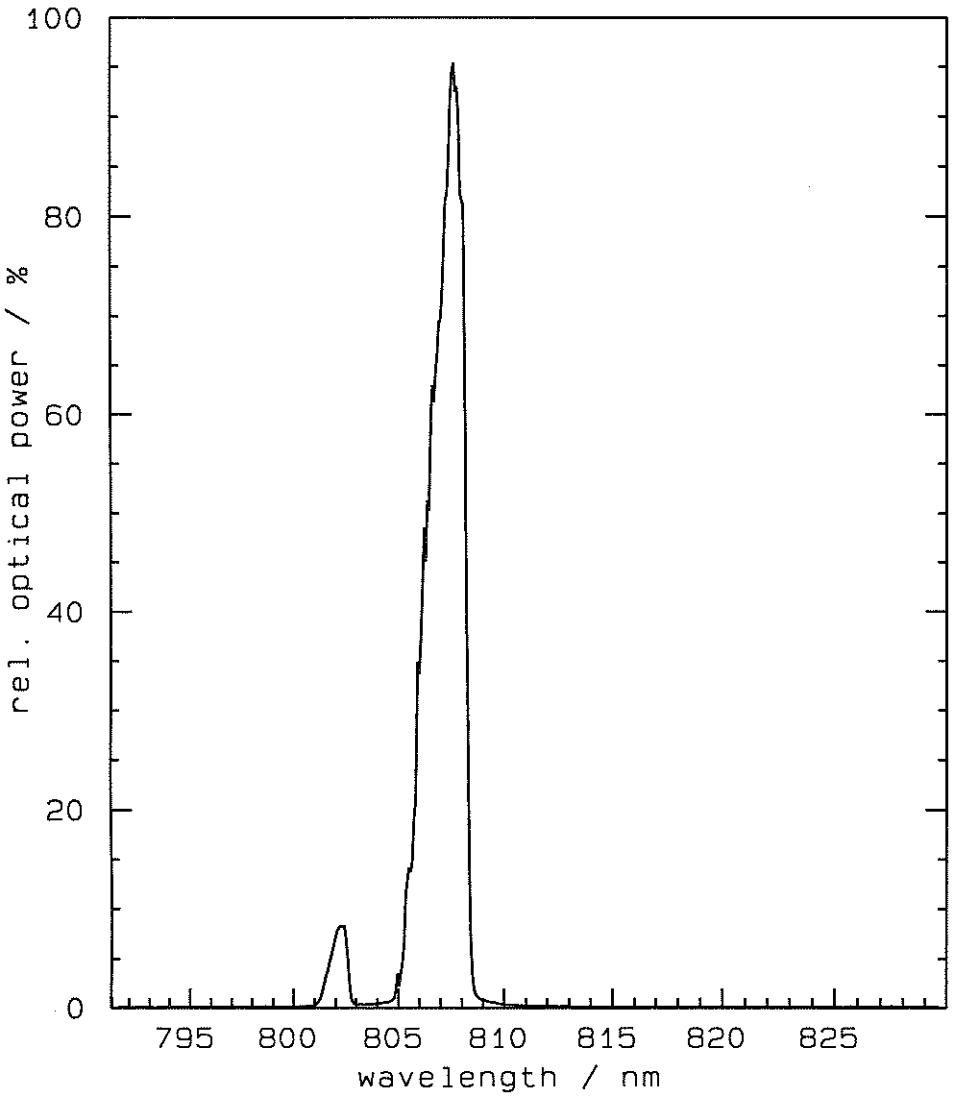
JENOPTIK GERMANY

JENOPTIK Laserdiode GmbH
Goeschwitzer Strasse 29 I 07745 Jena I Germany
Sales contact: Diode Laser Group of Jenoptik
Phone: +49 3641 65-4300 I Fax: +49 3641 65-4392
E-mail: dlg@jenoptik.com I www.jenoptik-dlg.com

QUALITY MANAGEMENT Certificate
Voluntary participation in regular monitoring according to ISO 9001:2000

9-13-07 5: 35

Spectrum



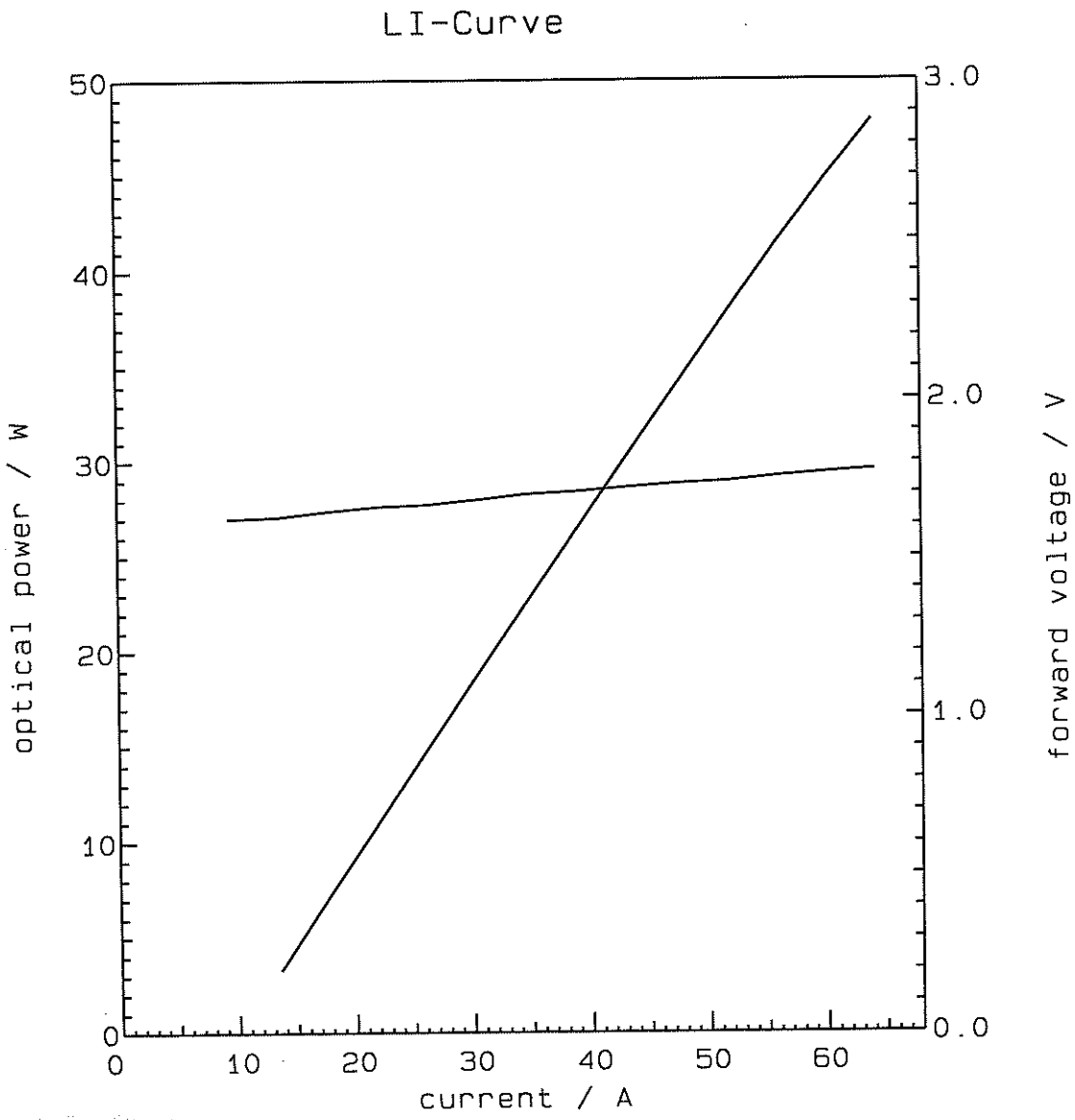
Device No.	:	RC071174
Heatsink temperature	:	25 deg C
pulse length	:	cw
wavelength (90%-width)	:	807.0 (3.1) nm
spectral FWHM	:	1.9 nm
threshold current	:	9.9 A
slope efficiency	:	0.89 W/A
operating current for 45W	:	60.7 A
series resistance	:	2.9 mOhm
efficiency at 45 W	:	42.0 %
photodiode voltage at 8W	:	0.984 V
photodiode voltage at 16W	:	1.974 V
laserdiode voltage at 45W	:	1.766 V
laserdiode voltage at 15W	:	1.669 V

final inspection : ..D. Treb....

(gemessen auf RGB-Messplatz)

JENOPTIK Laserdiode GmbH

9-13-07 5: 36



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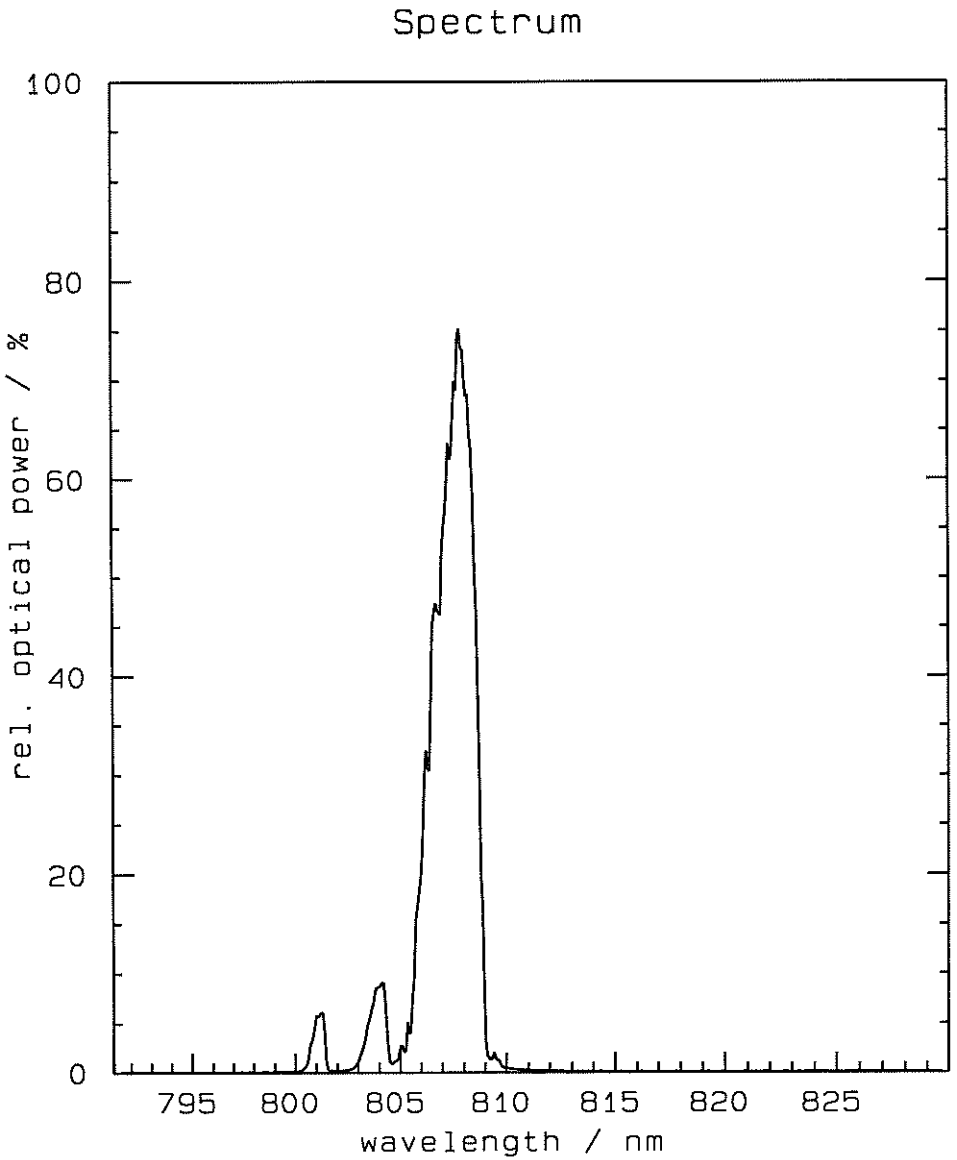
laserdiode voltage at 15W	:	1.669 V

final inspection : ..D. Tuebs....

(gemessen auf RGB-Messplatz)

JENOPTIK Laserdiode GmbH

9-13-07 6:00



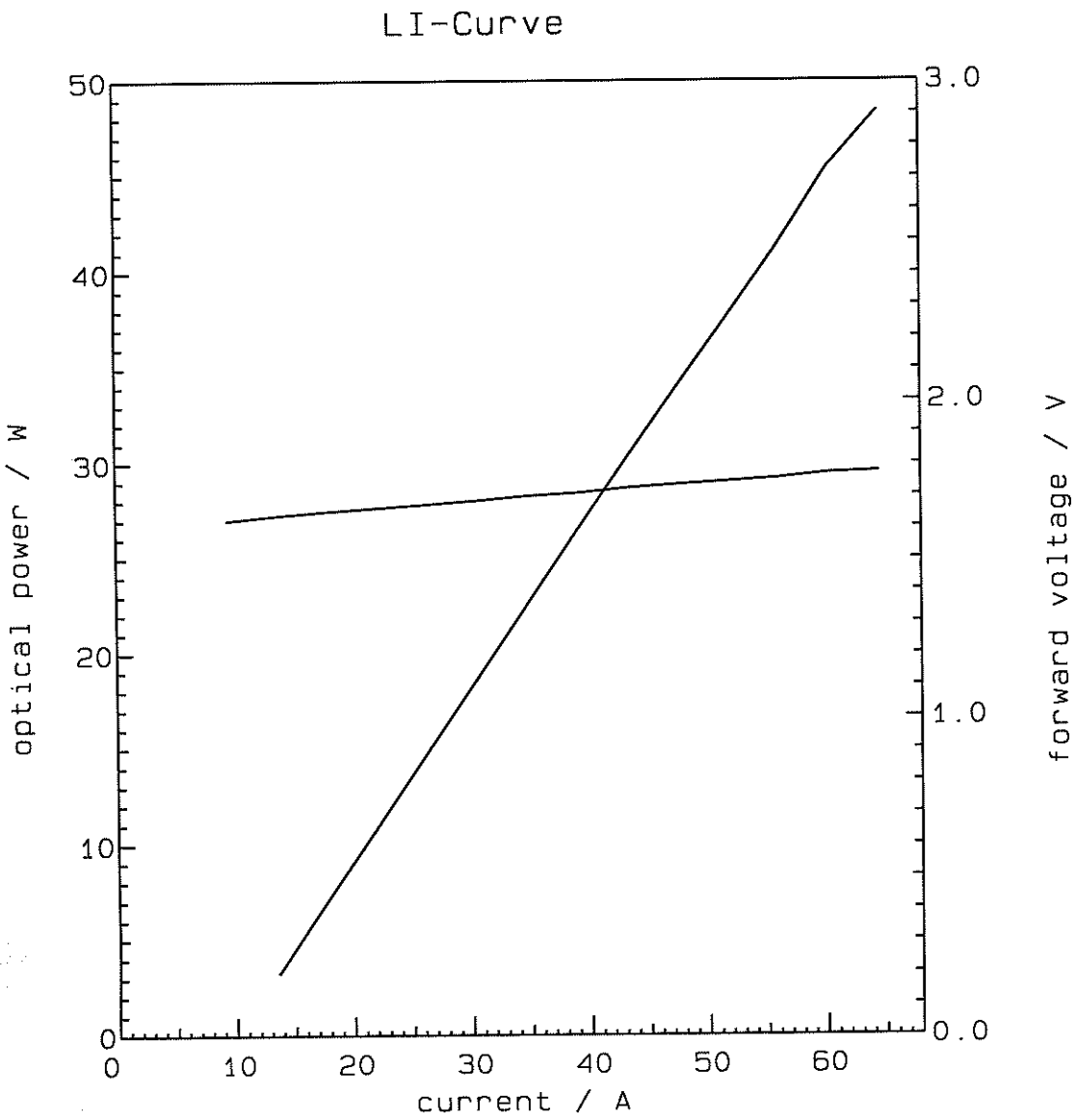
Device No.	:	RC071175
Heatsink temperature	:	25 deg C
pulse length	:	cw
wavelength (90%-width)	:	807.2(5.1)nm
spectral FWHM	:	2.2 nm
threshold current	:	10.1 A
slope efficiency	:	0.89 W/A
operating current for 45W	:	60.5 A
series resistance	:	2.8 mOhm
efficiency at 45 W	:	42.1 %
photodiode voltage at 8W	:	1.060 V
photodiode voltage at 16W	:	2.077 V
laserdiode voltage at 45W	:	1.766 V
laserdiode voltage at 15W	:	1.672 V

final inspection : D. Trieb

(gemessen auf RGB-Messplatz)

JENOPTIK Laserdiode GmbH

9-13-07 6:00



Device No.	:	RC071175
Heatsink temperature	:	25 deg C
pulse length	:	cw
wavelength (90%-width)	:	807.2(5.1)nm
spectral FWHM	:	2.2 nm
threshold current	:	10.1 A
slope efficiency	:	0.89 W/A
operating current for 45W	:	60.5 A
series resistance	:	2.8 mOhm
efficiency at 45 W	:	42.1 %
photodiode voltage at 8W	:	1.060 V
photodiode voltage at 16W	:	2.077 V
laserdiode voltage at 45W	:	1.766 V
laserdiode voltage at 15W	:	1.672 V

final inspection : ...D. Trubs...

(gemessen auf RGB-Messplatz)

JENOPTIK Laserdiode GmbH

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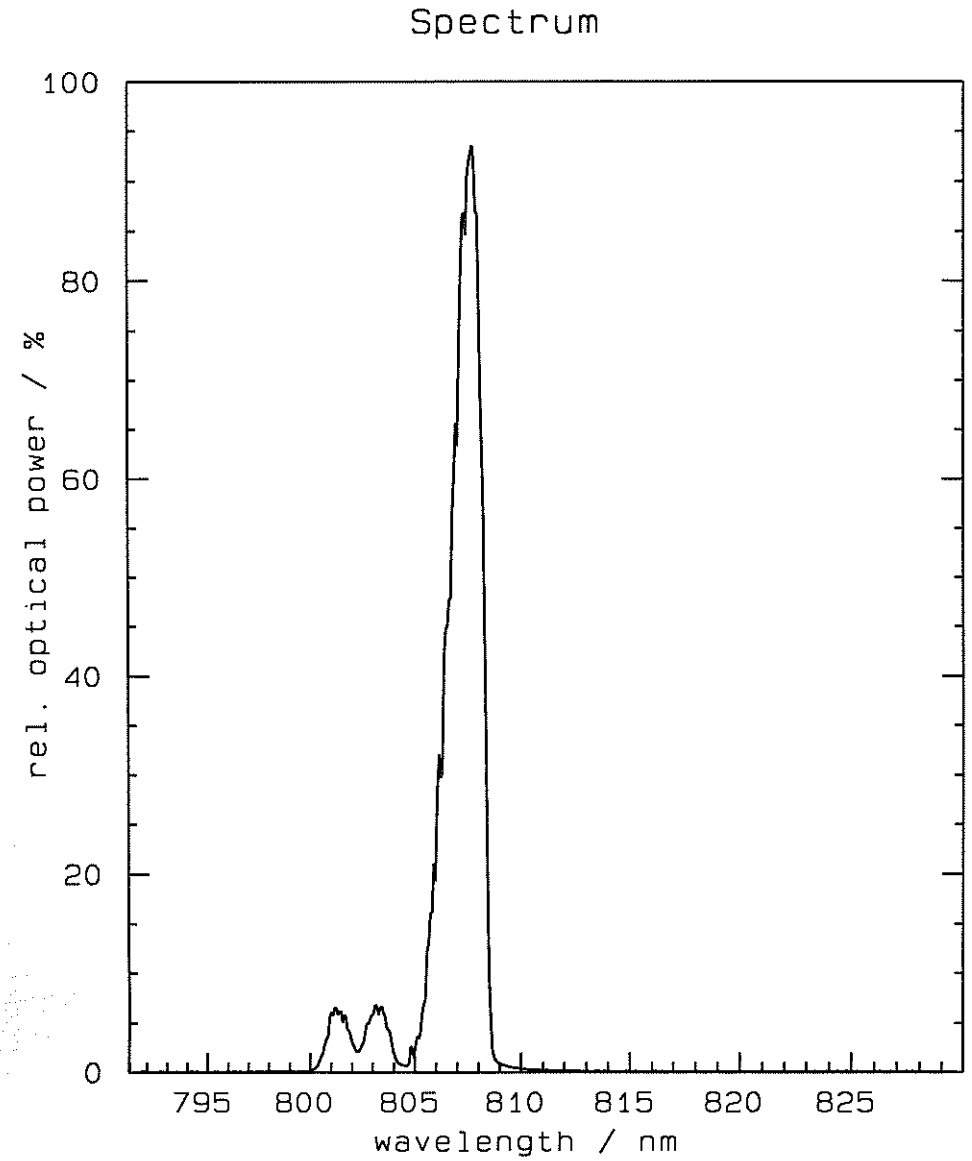


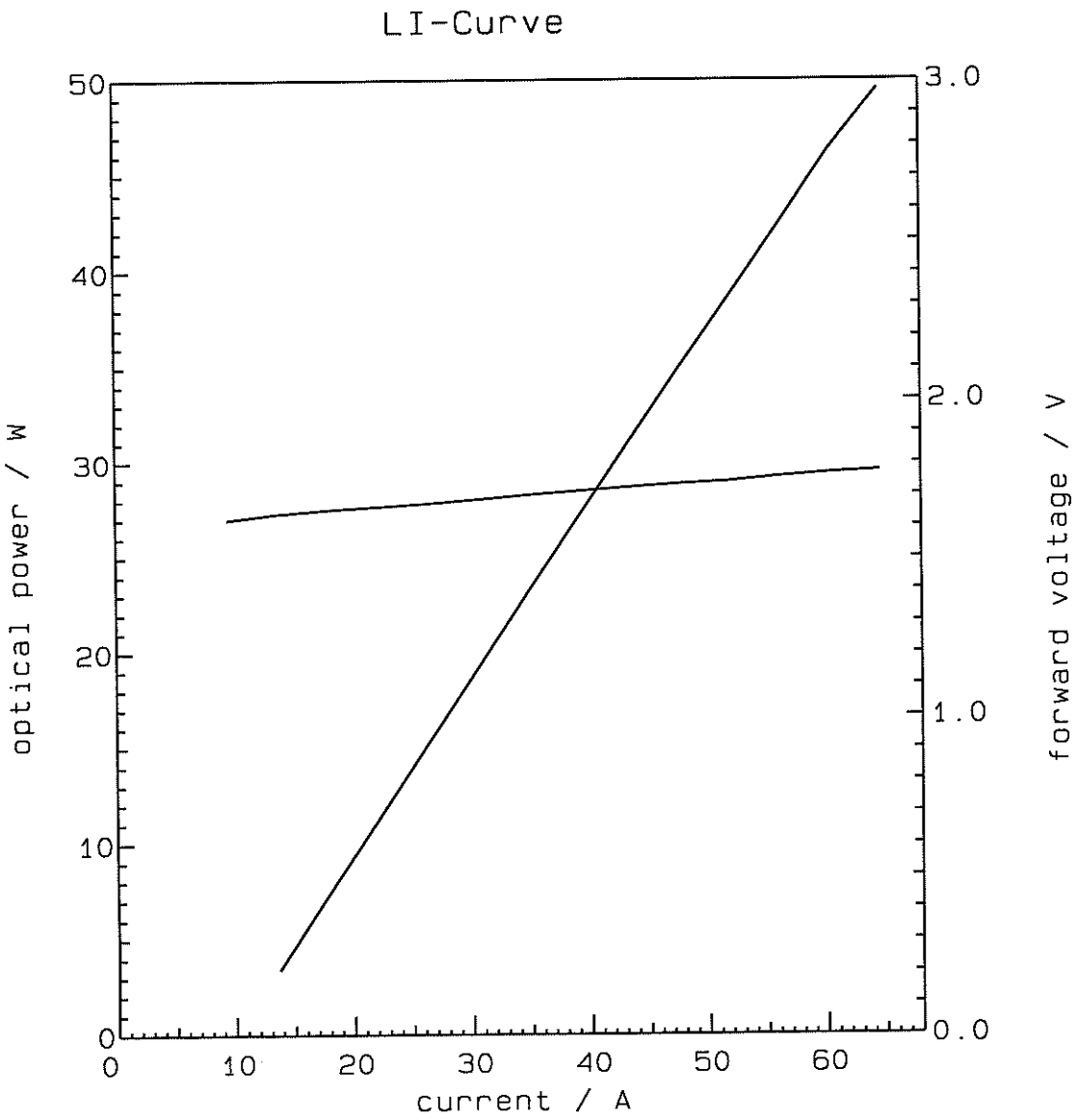
Device No.	:	RC071176
Heatsink temperature	:	25 deg C
pulse length	:	cw
wavelength (90%-width)	:	806.9 (6.6) nm
spectral FWHM	:	1.6 nm
threshold current	:	10.0 A
slope efficiency	:	0.91 W/A
operating current for 45W	:	59.5 A
series resistance	:	2.7 mOhm
efficiency at 45 W	:	42.9 %
photodiode voltage at 8W	:	1.027 V
photodiode voltage at 16W	:	2.032 V
laserdiode voltage at 45W	:	1.763 V
laserdiode voltage at 15W	:	1.672 V

final inspection : D. Trebs

(gemessen auf RGB-Messplatz)

JENOPTIK Laserdiode GmbH

9-13-07 6:20



Device No.	:	RC071176
Heatsink temperature	:	25 deg C
pulse length	:	cw
wavelength (90%-width)	:	806.9 (6.6) nm
spectral FWHM	:	1.6 nm
threshold current	:	10.0 A
slope efficiency	:	0.91 W/A
operating current for 45W	:	59.5 A
series resistance	:	2.7 mOhm
efficiency at 45 W	:	42.9 %
photodiode voltage at 8W	:	1.027 V
photodiode voltage at 16W	:	2.032 V
laserdiode voltage at 45W	:	1.763 V
laserdiode voltage at 15W	:	1.672 V

final inspection : D. Trebs

(gemessen auf RGB-Messplatz)

JENOPTIK Laserdiode GmbH

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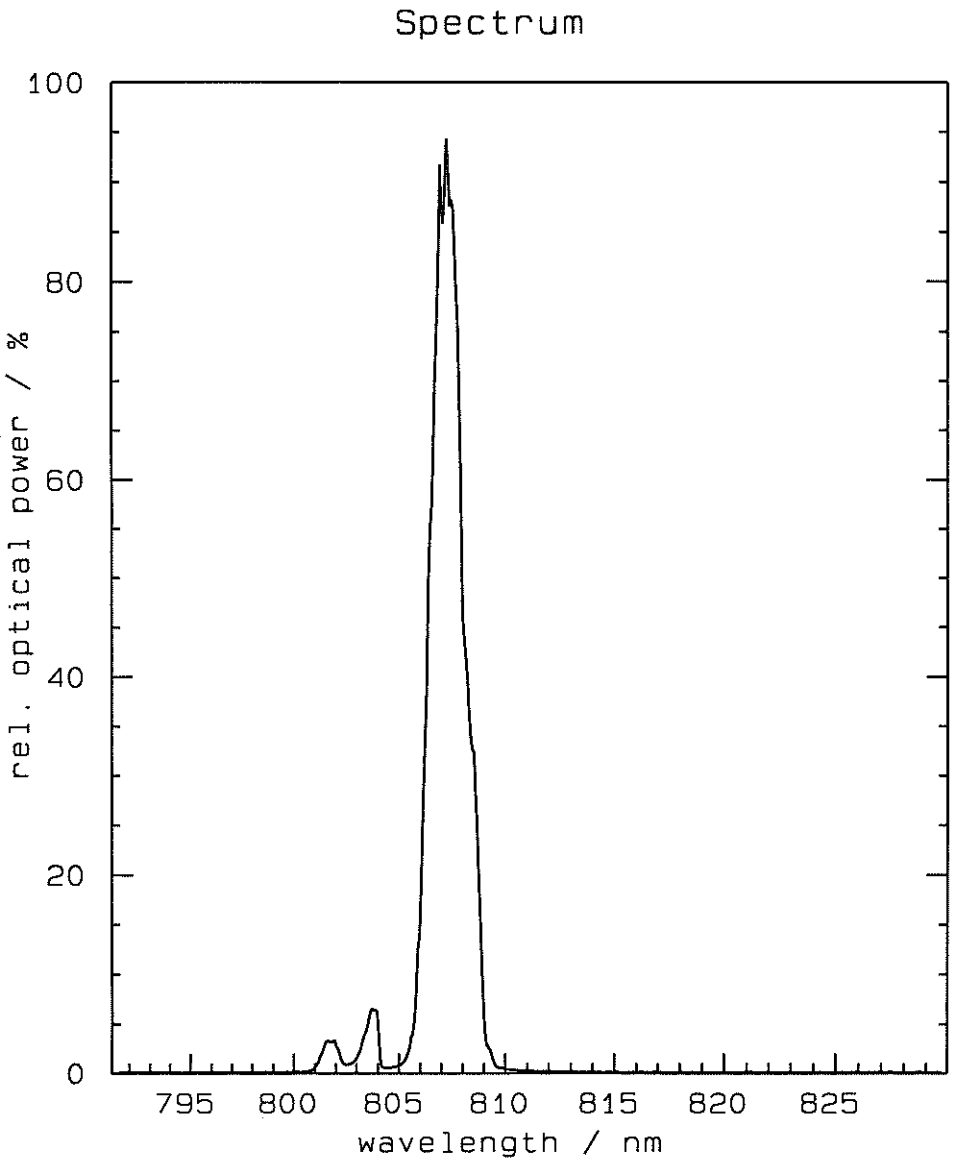

Device No.	:	RC071177
Heatsink temperature	:	25 deg C
pulse length	:	cw
wavelength (90%-width)	:	807.2(3.5)nm
spectral FWHM	:	1.6 nm
threshold current	:	9.8 A
slope efficiency	:	0.88 W/A
operating current for 45W	:	60.7 A
series resistance	:	2.8 mOhm
efficiency at 45 W	:	42.0 %
photodiode voltage at 8W	:	0.969 V
photodiode voltage at 16W	:	1.936 V
laserdiode voltage at 45W	:	1.766 V
laserdiode voltage at 15W	:	1.672 V

final inspection : ..D. Tr6.....

(gemessen auf RGB-Messplatz)

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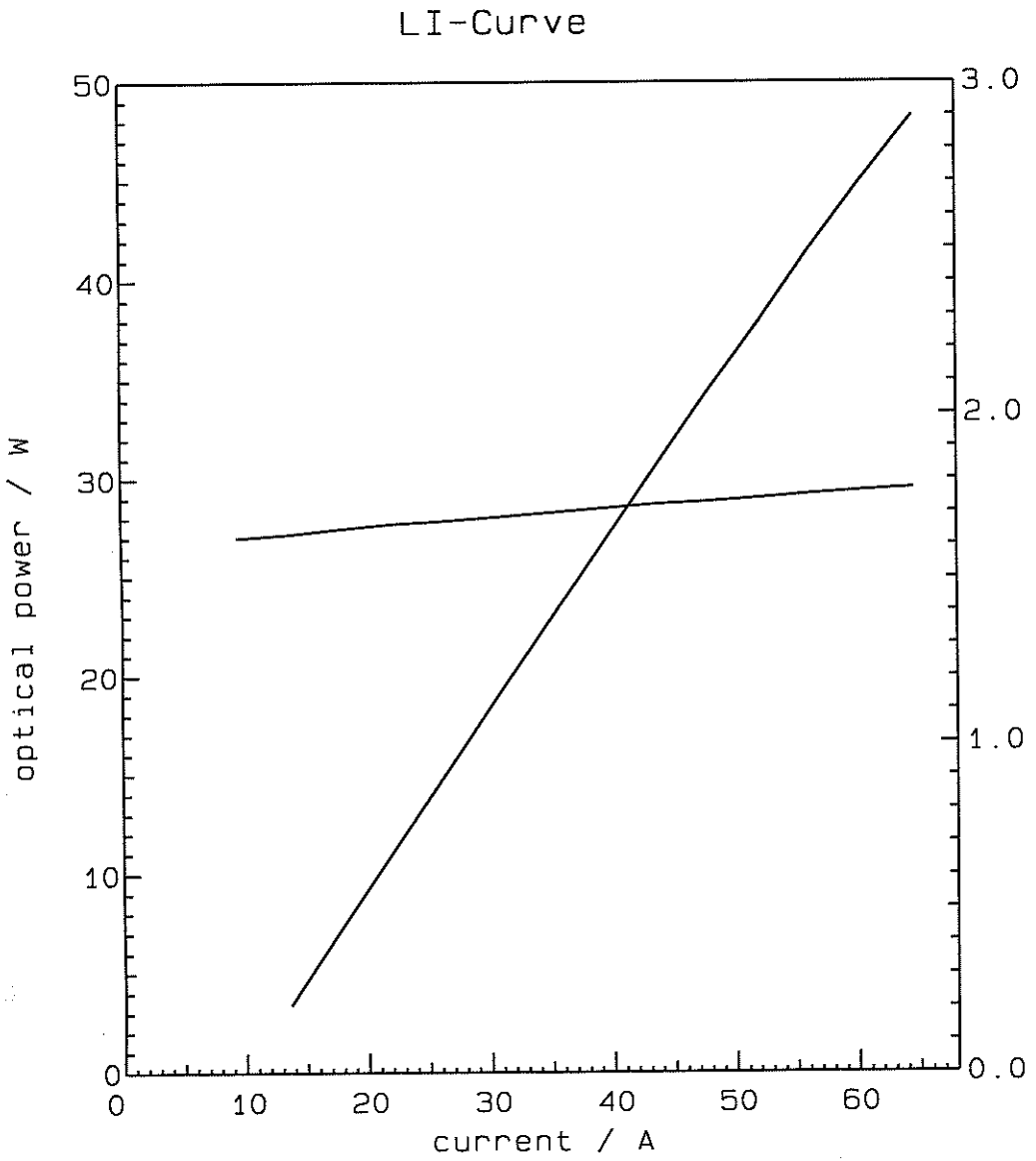

Device No.	:	RC071177
Heatsink temperature	:	25 deg C
pulse length	:	cw
wavelength (90%-width)	:	807.2(3.5)nm
spectral FWHM	:	1.6 nm
threshold current	:	9.8 A
slope efficiency	:	0.88 W/A
operating current for 45W	:	60.7 A
series resistance	:	2.8 mOhm
efficiency at 45 W	:	42.0 %
photodiode voltage at 8W	:	0.969 V
photodiode voltage at 16W	:	1.936 V
laserdiode voltage at 45W	:	1.766 V
laserdiode voltage at 15W	:	1.672 V

final inspection : ...

(gemessen auf RGB-Messplatz)

JENOPTIK Laserdiode GmbH

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Germany

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E-mail: jold@jenoptik.com
www.jold.com

Safety and Handling Instructions

For complete Instructions see General User Information!

1. Diode Laser Safety and General Handling Instructions

1.1 Safety Instructions

All JENOPTIK Laserdiode GmbH (JOLD) high power diode lasers are - according to IEC-Standard International Electronical Commission (IEC Standard; Publication 825, 1993) - class 4 laser products. The IEC Standard includes safety regulations for eye and personnel protection, that must be observed to avoid any harm to operating personnel.

Persons working with high power diode lasers must wear suitable laser protection glasses. The diode laser beam must not hit anyone's eye, because it may cause irreversible damage of the eye's retina.

Diode lasers should be operated in a light-tight box, the door of which should be equipped with a switch, that shuts down the diode laser when the door is opened.

1.2 Storage and Shipping

Storage and shipping of diode lasers must be done with shortened electrical contacts and in a clean and dry atmosphere in a temperature range of 0°C up to 60°C.

1.3 Handling

Read this instruction carefully before unpacking to avoid damage of the diode lasers. Diode lasers should be handled and operated by qualified personnel only! Any violation of these instructions results in total loss of any warranty.

Every person and each tool that might get into contact with the diode laser must be continuously **grounded**. Diode lasers are very sensitive to over-voltages. Thus, their handling requires strict precautions against electrostatic charges.

Diode lasers must be operated with a suitable power supply in regulated current mode only, as even very short current or voltage spikes may destroy them. Precautions against spiking during switching on or off the power supply must be assured. Correct polarity of the power supply must be assured, because even small reverse voltages can cause irreversible damage of the diode laser.

Solvents, plastics, glues and heat conductive paste are not allowed near the diode lasers, because solvents could emerge and deposit on the facets. The semiconductor crystal and its coatings are very sensitive to any kind of solvents and liquids.

The diode lasers must be handled in a clean and dry atmosphere. Cleanroom conditions locally around open diode lasers better than class 1000 and less than 60% relative humidity are recommended. There is no way to clean the front facets neither by solvents nor by mechanical tools. Especially, the diode laser front facet is extremely sensitive and must be kept free of dust, water and any other kind of contamination. Any contact to the laser front facet will lead to irreversible damage and failure of the diode laser, even if there is

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no sudden failure. Soldering near the diode laser must be avoided. Fastening of the diode laser and connecting cables must be done by the way described in the manual. Diode lasers are also sensitive against thermal and mechanical stress.

2. Unpacking and Operating Instructions

2.1 Unpacking

The JOLD high power diode lasers are shipped in a conductive plastic shipping container, that is packed in a dry nitrogen filled sealed plastic bag. Before opening the plastic bag, diode lasers should be kept for at least 4 hours in the rooms where the bag will be opened to achieve thermal equilibrium. The protective bag may be opened only in a clean environment and non-humide atmosphere (see 1.3).

Handling personnel and tools must be **grounded for ESD-protection** purposes.

After opening the sealed bag the shipping container can be removed and carefully be opened. The diode lasers are screwed to a fixing plate by a fixing screw. Do not loosen the assembly screws, that keep the diode laser together. Take a look into the appropriate drawing and find the fixing screws. The fixing screw is tied in the way, that it also assures a short-circuit between the two diode laser contacts. During handling the personnel should wear clean gloves and use plastic tweezers for not to contaminate the facets of the diode lasers.

Never touch the laser front facet with any kind of object!

For removing a diode laser from the fixing plate unscrew only the fixing screw with a suitable screw driver.

Pay special attention not to scratch the bottom surface of passively cooled diode lasers. Scratches will increase the thermal resistance of the mounted device and reduces the heat dissipating capacity, which might result in reduced efficiency and thermal overload of the diode laser.

2.2 Operating Conditions and Mounting

In general, appropriate cooling of the diode lasers is necessary. Before the diode lasers are put to operation, they must be screwed to a flat submount surface, that is actively cooled in case of a passively cooled diode laser to remove the dissipating heat. Passively cooled diode lasers must not be operated without proper thermal contact to a cooled submount surface.

Diode laser degradation accelerates with increased temperature. Therefore, housing or heatsink temperature should be minimized where possible. Lowering the diode laser temperature below 15 °C is only suitable in a closed housing with dry inert atmosphere (e.g. Nitrogen). **Condensation of water or other liquids irreversibly damages the diode lasers.**

Diode lasers should be operated only in dust free environment. High electrical fields near the active region attract dust particles, that cause irreversible damage of the facets during operation.

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E-mail: jold@jenoptik.com
www.jold.com

The submount surface should be finely milled or lapped (flatness: 0.5 µm, roughness: 0.5 µm), clean and free of scratches to guarantee good thermal contact. It must be kept at constant temperature (typically 25°C) even under thermal load. The diode laser must be tightly screwed to this surface through the center mounting hole with an appropriate screw at specified torque that is given in the operating instuctions of each device.

No heat conductive paste between diode laser and mounting surface may be used because of the risk of emerging solvents.

2.3 Operating Instructions

Observe laser safety precautions!

Ensure that your diode driver is suitable for diode laser operation.

Switch off and shorten the power supply before contacting the diode laser.

Assure that all connectors in the electrical circuit guarantee a good contact. Soldering of the connecting cable to the diode laser is not allowed. Electrical cables should be arranged in a low-inductance constellation to avoid any tendency towards current oscillations.

If the diode laser has to be electrically insulated from the mounting surface, insulation may only be achieved by a thin flat ceramic plate of high thermal conductivity. Plastic insulation foil (e.g. Kapton) will effect laser lifetime because of an increased thermal resistance and possible solvent emerging that might damage the semiconductor crystal. Preferrably, diode lasers with an insulated heatsink bottom surface should be ordered. If the diode laser is mounted electrically insulated the p-connection to the power supply must be done by the provided connector at the diode laser rear side.

Before switching on the power supply assure that the current preset is set to zero. Then, switch on the power supply and increase the current slowly.

Do not exceed the operating current for the nominal output power according to the supplied measurement data sheet!

By definition, the end of life of a high power diode laser is reached at the point in time at which the output power at constant current shows a reduction of 20%. To counter the effect of power loss, the operation current can be increases by up to 20% in order to maintain the nominal optical output power.

Check the emission wavelength at the specified current. A much longer wavelength than specified indicates bad thermal contact and thermal overload of the diode laser. Then the thermal contact has to be improved before continueing laser operation. (The emission wavelength shifts by approx. 0.25..0.30 nm/K.)

Actively cooled diode laser should only be operated with deionized water. The water circuitry should contain a ion exchanger cartridge to keep the conductivity at 5..10 µS/cm. All materials in contact with water should be suitable for deionized water (copper, food-grade steel and plastics). Don't use any materials leading to galvanic elements with copper (aluminum, zinc etc.). Avoid bubble generation and superficial oxygen intake!

JENOPTIK Laserdiode GmbH
Goeschwitzer Strasse 29
07745 Jena
Germany

Phone +49 3641 65-4300
Fax +49 3641 65-4399
E-mail: jold@jenoptik.com
www.jold.com

3. Warranty

Unless otherwise specified, all JOLD diode lasers are individually inspected, tested and certified before they are shipped to the customer.

Seller shall warrant, that the goods at the time when the risk passes over to purchaser are not affected by defects that will not insignificantly cancel or deteriorate the value or the fitness for ordinary use or the use supposed by the contract.

Seller shall assume no warranty for damages caused by unsuitable or improper use, non-observance of indications for application or by defective or negligent handling as well as by natural wear. Diode lasers that give any visual hints of mishandling can not be replaced, even, if this was not the initial reason for returning. Those devices are

- diode lasers with contaminated or scratched thermal contact surfaces, even if no other mishandling is assessable, because these defects influence the characteristics (P, I, λ) basically by an increased thermal resistance.
- diode lasers with contaminated or damaged facets.
- diode lasers with burned spots or spewing near the active region. (Caused by oversized current, current transients or deposited particles burning the facets by absorbing the output energy.)
- mechanical damage on any parts (e.g. lifted off contact foil, broken laser chip, deformed heatsinks), even if this damage happened after the returning reason arose.

Seller's deliveries have to be inspected after receipt. Nonmerchants have to complain obvious defects within two weeks by writing stating the number of diode laser serial number and the delivery note, otherwise the warranty is excluded. For merchants §§ 377, 378 HGB (Commercial Code) shall remain.

Defects that are assessable during the incoming inspection, cannot be considered after diode lasers were put into operation, because later induced defects or degradation disguise the initial defect reason.

The warranty for the delivered diode lasers shall be first limited to rectification or replacement of the defect diode lasers.

If the second attempt of rectification or replacement (in case of quality defects) or supplementary delivery (in case of quantity defects) by seller fails purchaser shall be entitled at his option to a reduction of the purchase price or cancellation of the contract (redhibition).

On seller's request purchaser shall be obliged to forward the good for the purpose of rectification, replacement or any other form of characterisation and confirmation. The costs for the dispatch and characterisation shall be borne by seller, if the defect is confirmed, otherwise they are charged to purchaser. As far as seller provides rectification or replacement from reasons of obligingness, purchaser shall bear the accrueing costs. If he wants to insist on the legal warranty he has to reject the offer of obligingness immediately.

The liability of seller for damages due to lack of warranted qualities shall remain unaffected.

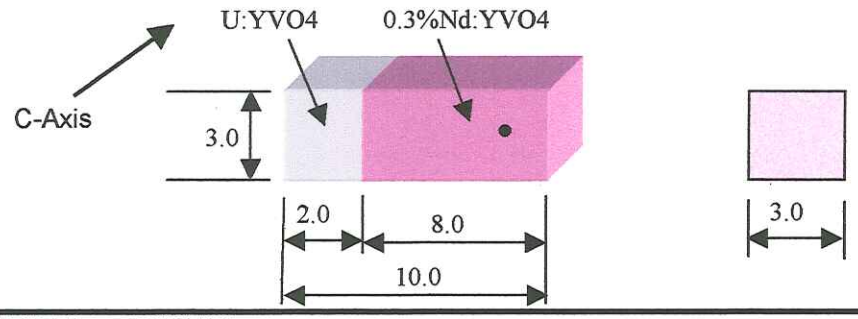
Onyx Optics, Inc.
6551 Sierra Lane
Dublin, CA 94568
TEL: 925-833-1969
FAX: 925-833-1759
www.onyxoptics.com

Company Name:	Laser Zentrum
Customer Name:	Bastian Schulz
P.O. Number:	566-2241-lw
Date:	7/8/2005
Item Number:	1
Batch Number:	12
Part Number:	2
Quantity:	1

Specification	Specified Value	Tolerance (if applicable)	Measured Value	Within Tolerance
Crystal quality	Free of bubbles	NA	Free of bubbles	Y
Total length	10.0mm	±0.1	10.07mm	Y
U:YVO4 length	2.0mm	±0.1	2.07mm	Y
0.3% Nd:YVO4 length	8.0mm	±0.1	8.0mm	Y
Final cross-section	3.0x3.0mm	±0.1	3.01x3.03	Y
Interface	Clear	NA	Clear	Y
3.0x10.0 Sides Finish (x4)	fine ground	NA	Fine ground	Y
End Face Surface Finish	10-5 scratch-dig	NA	10-5 scratch-dig	Y
End Face Surface Figure	λ/10	NA	λ/10	Y
End face parallelism	not specified	NA	10 arc seconds	Y

Coating

AR coated at 1064 and 808nm



NOTE: C-Axis has been marked on the side with a pencil dot.

Thermo Scientific
NESLAB
ThermoFlex™
Recirculating Chillers

Thermo Scientific Manual P/N U00933 Rev. 11/26/07

Installation
Operation
Basic Maintenance

Visit our Web site at:

http://www.thermofisher.com/tc

Product Service Information, Applications Notes, MSDS Forms, e-mail.

Voice Info: (800) 258-0830

Label 1

Label 2

Thermo Fisher Scientific

25 Nimble Hill Road
Newington, NH 03801
Tel : (800) 258-0830 or
(603) 436-9444
Fax : (603) 436-8411
www.thermofisher.com/tc

Sales, Service, and Customer Support

25 Nimble Hill Road
Newington, NH 03801
Tel: (800) 258-0830
Sales: 8:00 am to 5:00 pm
Service and Support: 8:00 am to 6:00 pm Monday through Friday (Eastern Time)
Fax: (603) 436-8411
service.tc.us@thermofisher.com

Dieselstrasse 4
D-76227 Karlsruhe, Germany
Tel : +49 (0) 721 4094 444
Fax : +49 (0) 721 4094 300
info.tc.de@thermofisher.com

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Xin Jinqiao Rd., Shanghai 201206
Tel : +86(21) 68654588
Fax : +86(21) 64457830
info.china@thermofisher.com

Contents

Quick Start - Used for Initial Start Up

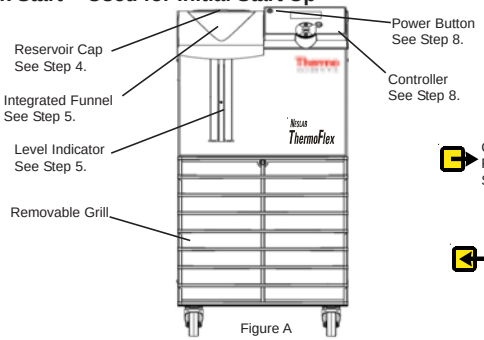


Figure A

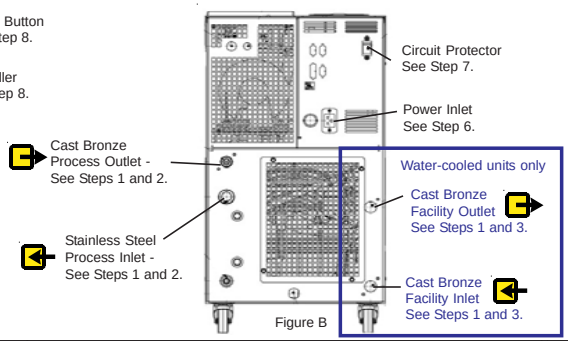
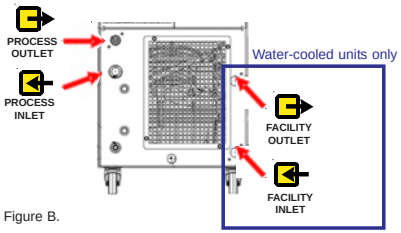


Figure B

What you need to get started:

- An adjustable wrench
- Facility water supply and return (water-cooled units)
- Appropriate hose or plumbing
- Appropriate size clamps or connection type
- Teflon® Tape or appropriate sealant

1 Pull out the plastic shipping plugs.



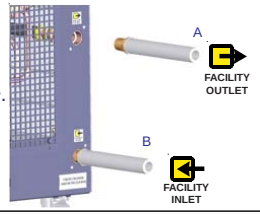
See Figure B.

2 Connect the ThermoFlex PROCESS OUTLET (A) to the fluid inlet on your application. Connect the ThermoFlex PROCESS INLET (B) to the fluid outlet on your application. Ensure the connections are sealed and secure. **For air-cooled units skip to Step 4.**

See Figure B.

3 Connect the ThermoFlex FACILITY OUTLET (A) to your facility water return or drain. Connect the ThermoFlex FACILITY INLET (B) to your facility water supply. Ensure the connections are sealed and secure.

For water-cooled units only.



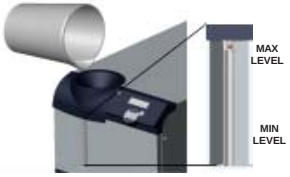
See Figure B.

4 Remove the reservoir cap by unscrewing it counter-clockwise.


See Figure A.

5 *Slowly* fill reservoir with clean process fluid (see Table 1), utilizing sight tube for easy fluid level monitoring. When the reservoir is full replace the reservoir cap. Since the reservoir capacity may be small compared to your application and air may need to be purged from the lines, have extra cooling fluid on hand to keep the system topped off when external circulation is started.

Note: Be careful not to fill the reservoir above MAX LEVEL fill line. This will result in a unit over flow error (O FLO) which will cause the unit to shut down.

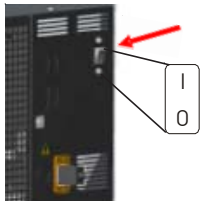


See Figure A.

6 Verify the appropriate voltage. Insert female end of power cord into chiller and then insert male end of power cord into power outlet.


See Figure B.

7 Place the circuit protector located on the rear of the unit to the on (**I**) position. The controller display will indicate a series of scrolling bars (≡ ≡). The bars will scroll upward indicating the controller is doing a self-test which takes approximately 15 seconds.



See Figure B.

8 Press ⏻.

The controller will display **SEtuP**.

Please see reverse side for additional steps.

See Figure A.

Safety Precautions:

The unit is designed for indoor use only.

Never place unit in a location where excessive heat, moisture, inadequate ventilation, or corrosive materials are present.

Never use flammable or corrosive fluids with this unit.

Never connect process fluid lines to your facility water supply or to any pressurized liquid source.

If your unit is equipped with a positive displacement (PD) pump, ensure your application plumbing lines and fittings are rated to withstand a minimum of 110 psi.

Before using any fluid or performing maintenance where contact with the fluid is likely refer to the manufacturer's MSDS for handling precautions.

Table 1.

Appropriate Fluids:
Filtered/Single Distilled Water
Deionized water (1-3 MOhmcm, compensated)
0 – 95% Ethylene Glycol/Water
0 – 95% Propylene Glycol/Water

Quick Start - Used for Initial Start Up Only
Perform steps 9 to 20 for all units.

NOTE: Once any Setup step is completed, meaning you pressed the enter key a second time, you cannot repeat the step to make corrections. You *can* make corrections after the unit is started, refer to the manual Section IV.

SEtuP — Press enter to continue the setup procedure.

9 UnitS — **UnitS are the temperature, fluid flow and pressure scales.**
Scales: °C/°F Liters/Gallons PSI/Bar
Factory Defaults: °C, Liters, PSI
- Press enter
- The display will flash between **UnitS** and **°C**
- If desired, use ▲ to change the scale to °F
- Press enter to sequence to the next display
- Do the same for **Liters** and **PSI**

10 Hi t — **Hi t sets the fluid's High Temperature Alarm Limit.**
Range: +4°C to +42°C
Factory Default: +42°C
- Press enter
- The display will flash between **Hi t** and **42**
- If desired, use ▲▼ to adjust the value
- Press enter to sequence to the next display

11 Lo t — **Lo t sets the fluid's Low Temperature Alarm Limit.**
Range: +4°C to +42°C
Factory Default: +4°C
- Press enter
- The display will flash between **Lo t** and **4**
- If desired, use ▲▼ to adjust the value
- Press enter

12 Hi P1 — **Hi P1 sets the Pump's High Pressure Discharge Alarm Limit.**
Range: 4 to 100 psi
Factory Default: 100 psi
- Press enter
- The display will flash between **Hi P1** and **100**
- If desired, use ▲▼ to adjust the value
- Press enter

13 dELAY — **dELAY is the length of time the pump can exceed the Hi P1 Alarm Limit before shutting down.**
Range: 0 to 30 seconds
Factory Default: 0 seconds
- The display will flash between **dELAY** and **0**
- If desired, use ▲▼ to adjust the value
- Press enter

14 Lo P1 — **Lo P1 sets the Pump's Low Pressure Discharge Alarm Limit.**
Range: 4 to 100 psi
Factory Default: 4 psi
- Press enter
- The display will flash between **Lo P1** and **4**
- If desired, use ▲▼ to adjust the value
- Press enter

15 dELAY — **dELAY is the length of time the pump can exceed the Lo P1 Alarm Limit before shutting down.**
Range: 0 to 30 seconds
Factory Default: 10 seconds
- The display will flash between **dELAY** and **10**
- If desired, use ▲▼ to adjust the value
- Press enter

16 ALr — **ALr configures the unit's reaction to temperature, pressure, and flow (optional) alarm limits - either shut down (fLt) or continue to run (indC). See manual for more information.**
Range: fLt* or indC**
Factory Default: fLt
- Press enter
- The display will flash between **ALr** and **fLt**
- If desired, press ▼ to display **indC**
- Press enter

***fLt = fault (shut down)**
****indC = indicate (continue to run)**

17 Sound — **Turns the unit's audible alarm on or off.**
Range: on or OFF
Factory Default: on
- Press enter
- The display will flash between **Sound** and **on**
- If desired, press ▼ to display **OFF**
- Press enter

18 StArt — **StArt enables/disables auto restart.**
Range: on or OFF
Factory Default: on
- Press enter
- The display will flash between **StArt** and **on**
- If desired, press ▼ to display **OFF**
- Press enter

19 CArE — **CArE is used to set the preventative care cleaning frequency reminder for the unit's air and fluid filters.**
Range: L1 - 1000 hours, L2 - 2000 hours, L3 -3000 hours
Factory Default: L1
- Press enter
- The display will flash between **CArE** and **L1**
- If desired, use ▲▼ to change display to L2 or L3
- Press enter

(If applicable, see boxes on right to set up options)

20 StorE
- Press ▲ to save all settings

The unit will automatically start.

- Press ▼ to abort all settings

The display will go blank

Press ⏻ to restart the procedure

The Setup procedure is now complete.

When the unit starts the controller will display the process fluid temperature.

If desired, you can change/verify the unit's setpoint by pressing mode

SP — **SP is used to adjust the setpoint.**
Range: +5°C to +40°C
Factory Default: +20°C
- The display will flash between **SP** and **20**
- If desired, use ▲▼ to change the setting
- Press enter to return to the temperature display

Option - Flow Transducer (Steps A and B)

A Hi FLo — **HiFLO sets the high flow alarm limit.**
Range: 0.5 to 5.0 GPM
Factory Default: 5.0 GPM
- Press enter
- The display will flash between **HiFLO** and **5.0**
- If desired, use ▲▼ to adjust the value
- Press enter

B LoFLo — **LoFLO sets the low flow alarm limit.**
Range: 0.5 to 5.0 GPM
Factory Default: 0.5 GPM
- Press enter
- The display will flash between **LoFLO** and **0.5**
- If desired, use ▲▼ to adjust the value
- Press enter

If your unit does not have serial communications see Step 20.

Option - Serial Communications (Steps C to H)

C SEr — **SEr is used to enable/disable and to configure serial communications mode.**
Range: off, rS232, rS485
Factory Default: off
- Press enter
- The display will flash between **SEr** and **OFF**
- If desired, use ▲▼ to change the mode
- Press enter

D BAud — **BAud is used to select the speed rate for serial communication.**
Range: 9600, 4800, 2400, 1200, 600, or 300 bits per second.
Factory Default: 9600
- Press enter
- The display will flash between **BAud** and **9600**
- If desired, use ▲▼ to change the rate
- Press enter

E dAtA — **dAtA is used to display the number of bits per communication.**
Display: 8
- Press enter
- The display will flash between **dAtA** and **8**
- Press enter

F StoP — **StoP is used to indicate the end of a communication's packet.**
Range: 2 or 1
Factory Default: 2
- Press enter
- The display will flash between **StoP** and **2**
- If desired, use ▲▼ to change the setting
- Press enter

G PAr — **PAr is used as a means to check for communication errors.**
Range: even, odd, or none
Factory Default: none
- Press enter
- The display will flash between **PAr** and **none**
- If desired, use ▲▼ to change the setting
- Press enter

H u id — **u id (unit id) is used in RS485 only. Identifies devices connected to the RS485 port.**
Range: 1 to 32
Factory Default: 1
- Press enter
- The display will flash between **u id** and **1**
- If desired, use ▲▼ to change the setting
- Press enter

See Step 20.

Preface

Compliance

Listed to:
UL 61010-1 2nd Edition
CSA C22.2 #6101.1 2nd Edition

Products tested and found to be in compliance with the requirements defined in the EMC standards defined by 89/336/EEC as well as Low Voltage Directive (LVD) 73/23/EEC can be identified by the CE Mark on the rear of the unit. The testing has demonstrated compliance with the following directives:

- LVD, 73/23/EEC IEC/EN 61010-1
- EMC, 89/336/EEC IEC/EN 61326-1

For any additional information, refer to the Declaration of Conformity that shipped with the unit.

WEEE/RoHS

This product is required to comply with the European Union's Waste Electrical & Electronic Equipment (WEEE) Directive 2002/96/EC . It is marked with the following symbol:

Thermo Fisher Scientific has contracted with one or more recycling/ disposal companies in each EU Member State, and this product should be disposed of or recycled through them. Further information on Thermo Fisher Scientific's compliance with these Directives, the recyclers in your country, and information on Thermo Scientific products which may assist the detection of substances subject to the RoHS Directive are available at:

www.thermo.com/WEEERoHS

After-sale Support

Thermo Fisher Scientific is committed to customer service both during and after the sale. If you have questions concerning the unit operation, or questions concerning spare parts or Service Contracts, call our Sales, Service and Customer Support phone number, see inside cover for contact information.

When calling, please refer to the labels on the inside cover. These labels list all the necessary information needed to properly identify your unit.

Feedback

We appreciate any feedback you can give us on this manual. Please e-mail us at neslabmanuals@thermofisher.com. Be sure to include the manual part number and the revision date listed on the front cover.

Warranty

Units have a warranty against defective parts and workmanship for 24 months from date of shipment. See back page for more details.

Unpacking

Retain all cartons and packing material until the unit is operated and found to be in good condition. If the unit shows external or internal damage contact the transportation company and file a damage claim. Under ICC regulations, this is your responsibility.

Out of Box Failure
An Out of Box Failure is defined as any product that fails to operate in conformance with sellers published specifications at initial power up. The unit must be installed in accordance with manufacturer's recommended operating conditions within 30 days of shipment from the seller.

Any Temperature Control product meeting the definition of an Out of Box Failure must be packed and shipped back in the original packaging to Thermo Fisher Scientific for replacement with a new unit; Seller to pay the cost of shipping. Customer must receive a Return Material Authorization (RMA) from Thermo Fisher prior to shipping the unit.

Section I Safety

Safety Warnings

Warnings are posted throughout the manual. These warnings are designated by an exclamation mark inside an equilateral triangle and text highlighted in bold. Read and follow these important instructions. Failure to observe these instructions can result in permanent damage to the unit, significant property damage, or personal injury or death.

The lightning flash with arrow symbol, within an equilateral triangle, is intended to alert the user to the presence of non-insulated "dangerous voltage" within the unit's enclosure. The voltage may be of significant enough magnitude to constitute a risk of electrical shock.

Make sure you read and understand all instructions and safety precautions listed in this manual before installing or operating your unit. If you have any questions concerning the operation of your unit or the information in this manual, please contact us. See inside cover for contact information.

Never place the unit in a location where excessive heat, moisture, or corrosive materials are present. ▲

The unit construction provides protection against the risk of electrical shock by grounding appropriate metal parts. The protection may not function unless the power cord is connected to a properly grounded outlet. It is the user's responsibility to assure a proper ground connection is provided. ▲

Always turn the unit off and disconnect the supply voltage from its power source before moving the unit. ▲

Never connect the process fluid inlet or outlet fittings to your building water supply or any water pressure source. ▲

Never use flammable or corrosive fluids with this unit. Use of these fluids will void the manufacturer's warranty. ▲

Do not use automotive antifreeze. Commercial antifreeze contains silicates that can damage the pump seals. Use of automotive antifreeze will void the manufacturer's warranty. ▲

Before using any fluid or performing maintenance where contact with the fluid is likely refer to the manufacturer's MSDS for handling precautions. ▲

Performance of installation, operation, or maintenance procedures other than those described in this manual may result in a hazardous situation and may void the manufacturer's warranty. ▲

Transport the unit with care. Sudden jolts or drops can damage the unit's components. ▲

If the unit is to be transported and/or stored in near or below freezing temperatures it needs to be drained, see Draining in Section VIII. The unit can be stored in the temperature range -25°C to 60°C (with packaging), and <80% relative humidity. ▲

The circuit protector located on the rear of the unit is not intended to be used as a disconnecting means. ▲

Observe all warning labels. ▲

Never remove warning labels. ▲

Never operate damaged or leaking equipment. ▲

Never operate the unit without process fluid in the reservoir. ▲

Always turn off the unit and disconnect the power cord from the power source before performing any service or maintenance procedures, or before moving the unit. ▲

Never operate the unit with panels removed. ▲

Never operate equipment with damaged power cords. ▲

Refer service and repairs to a qualified technician. ▲

Section II General Information

Description

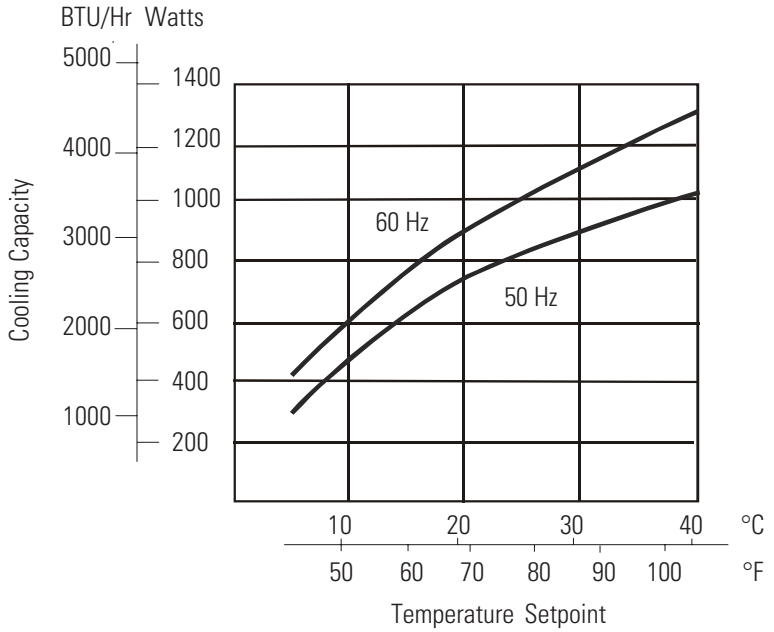
The Thermo Scientific NESLAB ThermoFlex™ recirculating chiller is designed to provide a continuous supply of fluid at a constant temperature and volume. The unit consists of an air-cooled or water-cooled refrigeration system, heat exchanger, recirculating pump, polyethylene reservoir, and a microprocessor controller.

Specifications

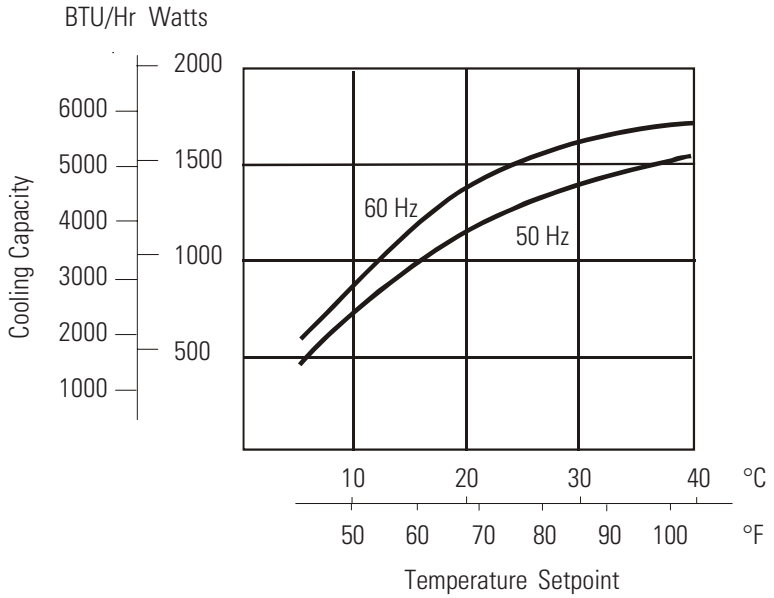
	ThermoFlex 900	ThermoFlex 1400	ThermoFlex 2500
Process Fluid Temperature Range	+ 5°C to +40°C +41°F to +104°F	+5°C to +40°C +41°F to +104°F	+5°C to +40°C +41°F to +104°F
Ambient Temperature Range	+ 10°C to +40°C + 50°F to +104°F	+10°C to +40°C +50°F to +104°F	+10°C to +40°C +50°F to +104°F
Temperature Stability	± 0.1°C	± 0.1°C	± 0.1°C
Cooling capacity at 20°C			
60 Hz	900 W (3072 BTU)	1400 W (4778 BTU)	2500 W (8538 BTU)
50 Hz	750 W (2560 BTU)	1170 W (3996 BTU)	2200 W (7513 BTU)
Reservoir Volume			
Gallons	1.9	1.9	1.9
Liters	7.2	7.2	7.2
Unit Weight (empty)			
lb	126	126	177
kg	57.2	57.2	80.3
Pumps			
PD 1 - Positive Displacement			
60 Hz		2.1 gpm @ 60 psi	
50 Hz		1.7 gpm @ 60 psi	
PD 2 - Positive Displacement			
60 Hz		4.1 gpm @ 60 psi	
50 Hz		3.3 gpm @ 60 psi	
Compliance		NRTL Certified to CSA and UL Standards; CE Marked	

- Specifications obtained at sea level using water as the recirculating fluid, at a 20°C process setpoint, 25°C ambient condition, at nominal operating voltage. Other fluids, fluid temperatures, ambient temperatures, altitude or operating voltages will affect performance.
- Thermo Fisher Scientific reserves the right to change specifications without notice.

ThermoFlex 900
Cooling Capacity

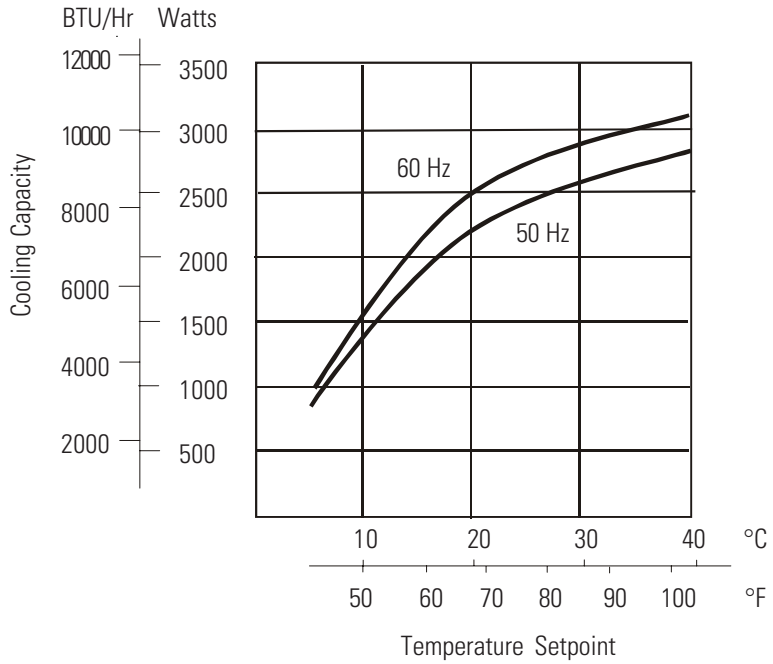


ThermoFlex 1400
Cooling Capacity

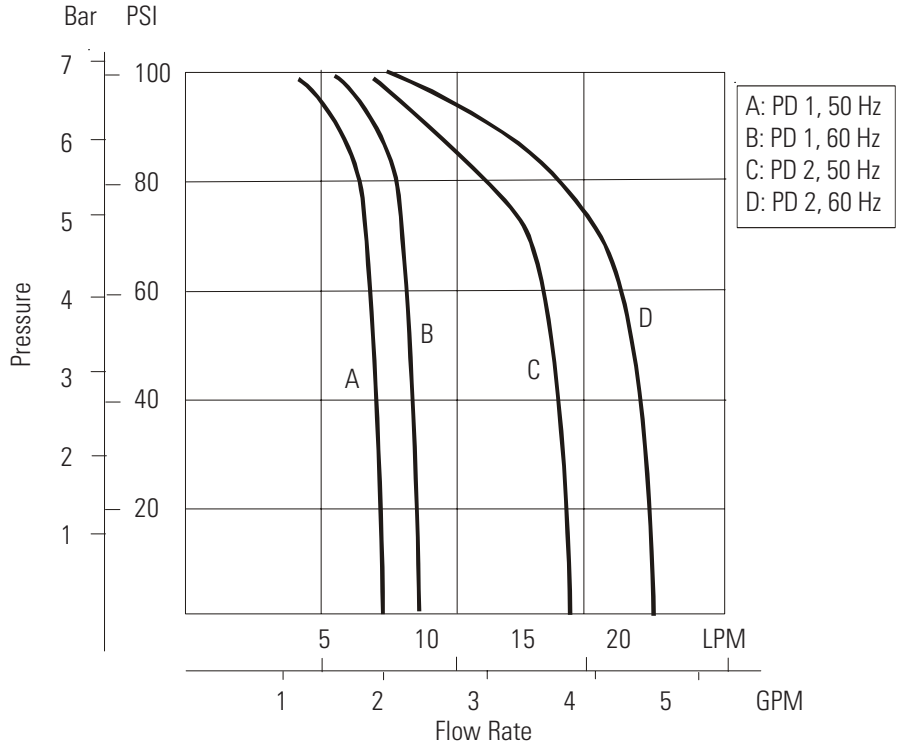


- Specifications obtained at sea level using water as the recirculating fluid, at a 20°C process setpoint, 25°C ambient condition, at nominal operating voltage. Other fluids, fluid temperatures, ambient temperatures, altitude or operating voltages will affect performance.
- Thermo Fisher Scientific reserves the right to change specifications without notice.

ThermoFlex 2500
Cooling Capacity

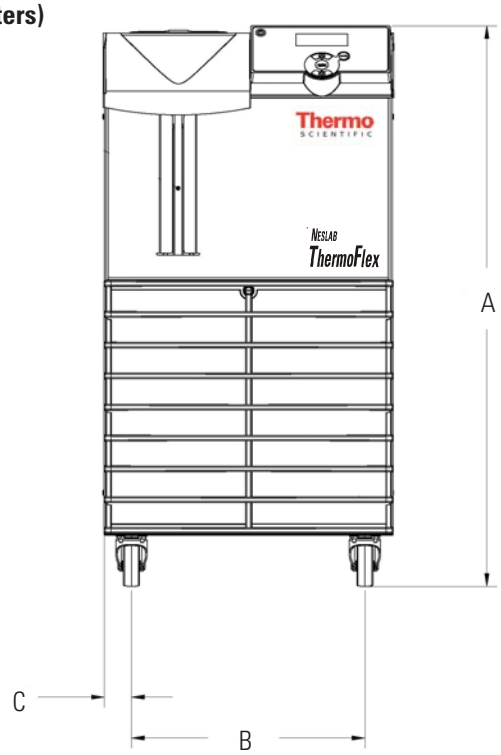


Pumping Capacity

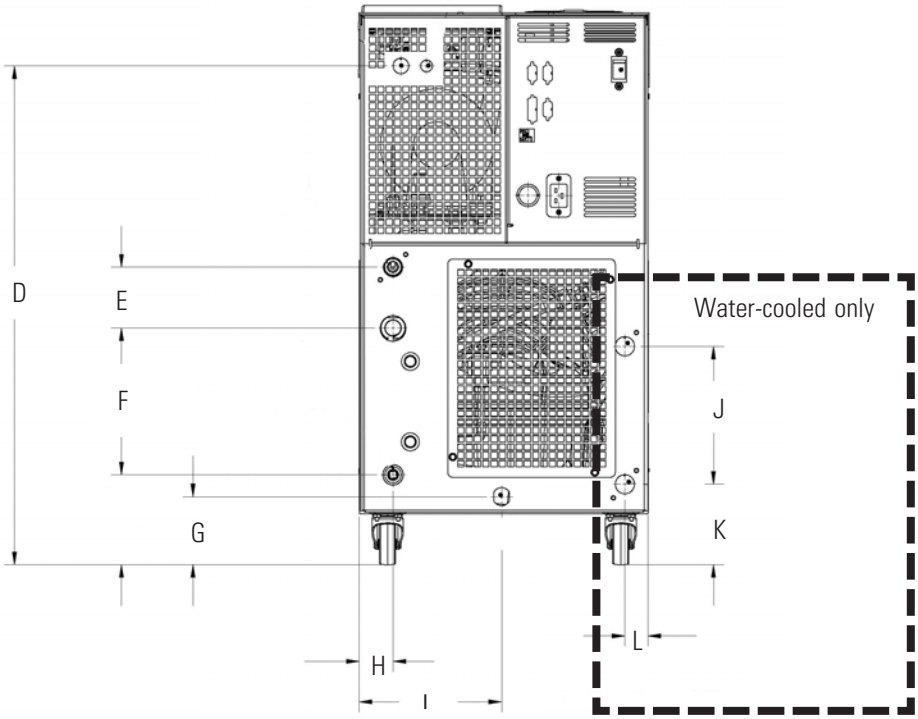


- Pump performance results were obtained with no restrictions on the return to the system.
- Specifications obtained at sea level using water as the recirculating fluid, at a 20°C process setpoint, 25°C ambient condition, at nominal operating voltage. Other fluids, fluid temperatures, ambient temperatures, altitude or operating voltages will affect performance.
- Thermo Fisher Scientific reserves the right to change specifications without notice.

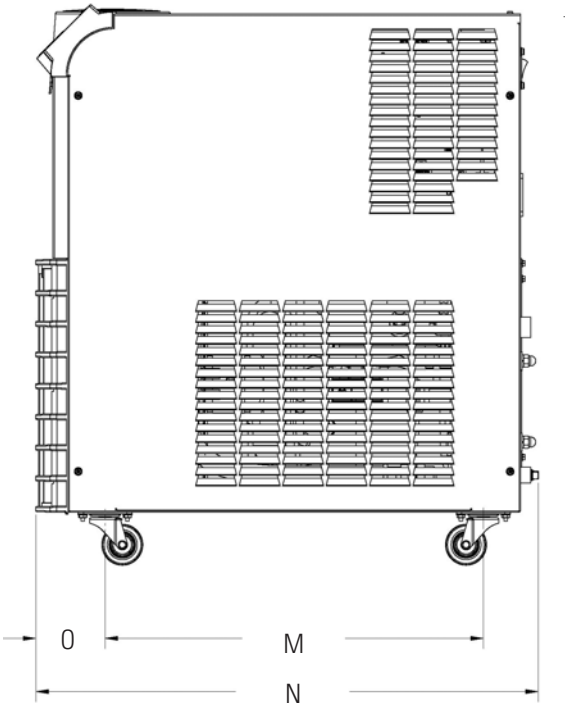
Unit Dimensions (Inches/ Centimeters)



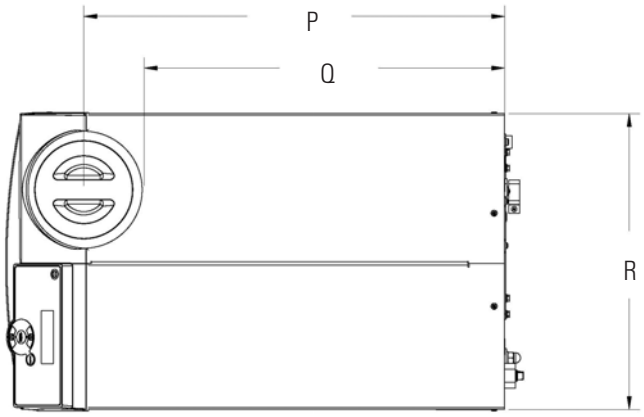
Front View



Rear View



Side View



Top View

Shipping crate dimensions:

ThermoFlex 900/1400	ThermoFlex 2500
21" wide	23" wide
35" tall	36" tall
40" deep	40" deep

	ThermoFlex 900/1400		ThermoFlex 2500	
A	27 5/16"	69.4 cm	29 1/16"	73.8 cm
B	11 3/8"	28.9 cm	13 3/8"	34.0 cm
C	1 3/8"	3.5 cm	1 13/16"	4.6 cm
D	24 7/16"	61.9 cm	26 1/16"	66.2 cm
E	3"	7.6 cm	3"	7.6 cm
F	11 9/16"	29.1 cm	13 3/16"	33.5 cm
G	4 3/8"	11.1 cm	6"	15.2 cm
H	1 5/8"	4.1 cm	1 5/8"	4.1 cm
I	6 15/16"	17.6 cm	6 9/19"	16.7 cm
J	6 3/4"	17.1 cm	7 13/16"	19.8 cm
K	3 15/16"	10.0 cm	5 1/16"	12.9 cm
L	1 1/8"	2.9 cm	1 3/16"	3.0 cm
M	18 1/2"	47.0 cm	20 1/16"	51.0 cm
N	24 9/16"	62.4 cm	25 11/16"	65.2 cm
O	3 3/8"	8.6 cm	3 9/16"	9.0 cm
P	20"	50.8 cm	22"	55.9 cm
Q	17 1/8"	43.5 cm	19 3/16"	48.7 cm
R	14 1/16"	35.7 cm	17 1/8"	43.5 cm

Section III Installation

Site Requirements

Ambient Temperature Range*	10°C to 40°C (50°F to 104°F)
Relative Humidity Range	10% to 80% (non-condensing)
Operating Altitude*	Sea Level to 8000 feet (2438 meters)
Overvoltage Category	II
Pollution Degree	2

Because of the decrease in air density, maximum temperature for the air entering the ThermoFlex must be reduced by 1°C per 1,000 feet above sea level. In addition, cooling capacity is reduced 1.2% per 1,000 feet above sea level.

Never place the unit in a location where excessive heat, moisture, inadequate ventilation, or corrosive materials are present. ▲

NOTE Fluid temperatures at the application may differ from the chiller due to environmental heat loss/gain. Heat is also lost through the plumbing when the setpoint is at or below room temperature. Applications with long lengths of plumbing may need to be insulated accordingly. ▲

Units installed below the end-user application may enable system fluid to drain back into the chiller and cause spillage. Thermo Fisher offers an anti-drainback kit to prevent any spillage, see Section V.

NOTE ThermoFlex 2500 air-cooled units are equipped with a two-speed fan. At 28°C ambient the fan speed will switch from slow speed to high speed to maintain internal temperatures within acceptable limits. If the ambient is 28°C or above, the unit will always be running the fan at high speed. Below 28°C the fan will run at either slow or high speed depending on the unit's internal ambient. When in high speed the unit's decibel level increases significantly. ▲

Air-cooled units can be installed with both sides blocked, or one side and the rear. See illustration below. The front of the unit needs a minimum clearance of 24". Air will enter the front of the system and exit through the sides and rear.

Having two sides blocked can impact the unit's performance due to changes in air flow. If your installation requires two blocked sides please ensure that the following requirements are met:

Process Setpoint Temperature: Below 30°C

Ambient: Below 40°C

If your unit will be operating in conditions outside any of those listed on this page please contact Thermo Fisher Scientific's Sales, Service and Customer Support to review your installation.

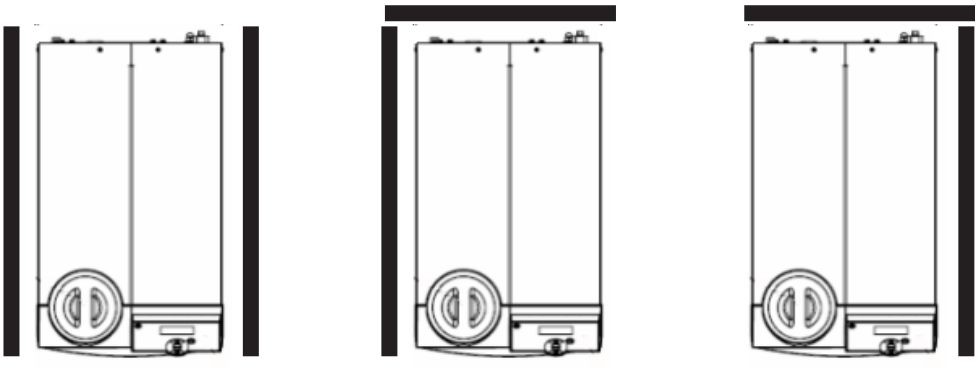


Figure 3-1 Minimum Clearance

Electrical Requirements

The unit construction provides protection against the risk of electrical shock by grounding appropriate metal parts. The protection may not function unless the power cord is connected to a properly grounded outlet. It is the user's responsibility to assure a proper ground connection is provided. ▲

The user is responsible to ensure that the power cord provided meets local electrical codes. If not, contact qualified installation personnel.

The unit is intended for use on a dedicated outlet. The ThermoFlex has an internal circuit protection that is equivalent (approximately) to the branch circuit rating. This is to protect the ThermoFlex, and is not intended as a substitute for branch circuit protection.

Electrical Service Requirements (Standard units):

ThermoFlex 900 Voltage	Frequency	Phase	Branch Circuit Requirements	Line Cord Plug
100 VAC	50 Hz	1Ø	15A	5-15P
115 VAC	60 Hz	1Ø	15A	5-15P
200 VAC	50 Hz	1Ø	15A	6-15P
208-230 VAC	60 Hz	1Ø	15A	6-15P
230 VAC	50 Hz	1Ø	*16A[1], 15A[2], 13A	-

ThermoFlex1400 Voltage	Frequency	Phase	Branch Circuit Requirements	Line Cord Plug
100 VAC	50 Hz	1Ø	20A	5-20P
115 VAC	60 Hz	1Ø	20A	5-20P
200 VAC	50 Hz	1Ø	15A	6-15P
208-230 VAC	60 Hz	1Ø	15A	6-15P
230 VAC	50 Hz	1Ø	*16A[1], 15A[2], 13A[3]	-

ThermoFlex 2500 Voltage	Frequency	Phase	Branch Circuit Requirements	Line Cord Plug
200 VAC	50 Hz	1Ø	20A	6-20P
208-230 VAC	60 Hz	1Ø	20A	6-20P
230 VAC	50 Hz	1Ø	*16A[1], 15A[2], 13A[3]	-

* Refer to Appendix A for country specific ratings.

Electrical Service Requirements (Global Voltage units):

ThermoFlex 900 Voltage	Frequency	Phase	Branch Circuit Requirements	Line Cord Plug
115 VAC	60 Hz	1Ø	15A	5-15P
100 VAC	50/60 Hz	1Ø	15A	5-15P
200/208/230 VAC	60 Hz	1Ø	15A	6-15P
200/230 VAC	50 Hz	1Ø	**16A[1], 15A[2], 13A[3]	6-15P

ThermoFlex1400 Voltage	Frequency	Phase	Branch Circuit Requirements	Line Cord Plug
115 VAC	60 Hz	1Ø	20A	5-20P
100 VAC	50/60 Hz	1Ø	20A	5-20P
200/208/230 VAC	60 Hz	1Ø	15A	6-15P
200/230 VAC	50 Hz	1Ø	**16A[1], 15A[2], 13A[3]	6-15P

ThermoFlex 2500 Voltage	Frequency	Phase	Branch Circuit Requirements	Line Cord Plug
200/208/230 VAC	60 Hz	1Ø	20A	6-20P
200/230 VAC	50 Hz	1Ø	**16A[1], 15A[2], 13A[3]	6-20P

** Units selected for 230 VAC operation have a range of -10% to +7%. Refer to Appendix A for country specific ratings.

For installation information on Global Voltage units refer to Appendix B.

Refer to the nameplate label located on the rear of the unit for specific electrical requirements.

Plumbing Requirements

Ensure that the shipping plugs are removed from all fittings before installation. ▲

Never connect the process fluid lines to your facility water supply or any pressurized liquid source. ▲

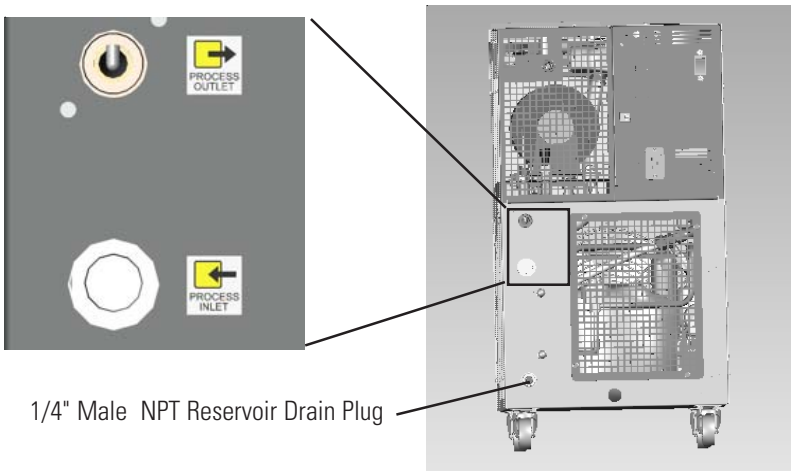


Figure 3-2 Plumbing Connections (1 of 2)

The process fluid plumbing connections are located on the rear of the unit and are labeled (PROCESS OUTLET) and (PROCESS INLET). The connections are ½" Female NPT. The process outlet connection is cast bronze, the process inlet connection is stainless steel.

Connect the PROCESS OUTLET to the fluid inlet on your application. Connect the PROCESS INLET to the fluid outlet on your application. Ensure all connections are secure and that the proper sealant/lubricant for the fitting material is used.

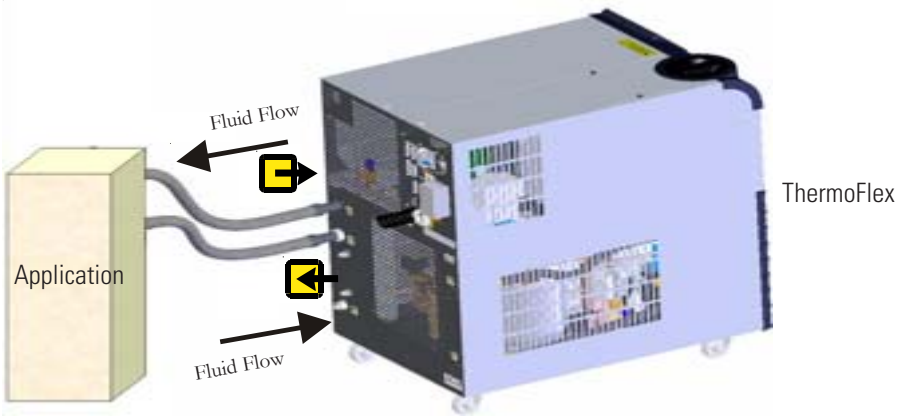


Figure 3-2 Plumbing Connections (2 of 2)

NOTE PD pumps are capable of producing 110 psi. Ensure your plumbing is rated to withstand this pressure. An external pressure relief valve is available, see Section V. ▲

Keep the distance between the unit and the instrument being cooled as short as possible. Tubing should be straight and without bends. If diameter reductions must be made, they should be made at the inlet and outlet of your application, not at the ThermoFlex.

Water-Cooled Units

For water-cooled units the facility water plumbing connections are also located on the rear of the unit and are labeled FACILITY INLET and FACILITY OUTLET. The connections are also ½" Female NPT. Both connections are cast bronze.

Connect the FACILITY INLET to your facility water supply. Connect the FACILITY OUTLET to your facility water return or drain. Ensure all connections are secure and that the proper sealant/lubricant for the fitting material is used.

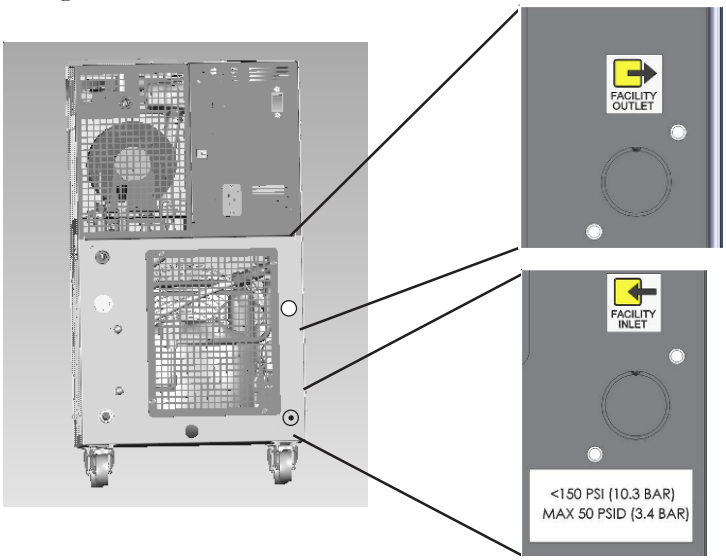
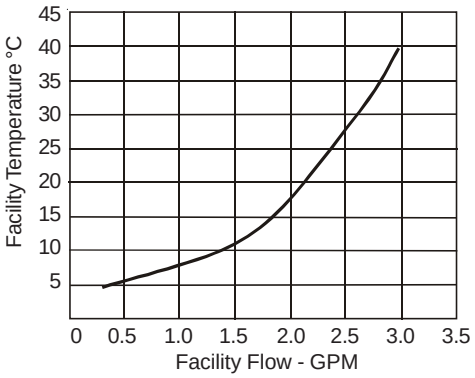


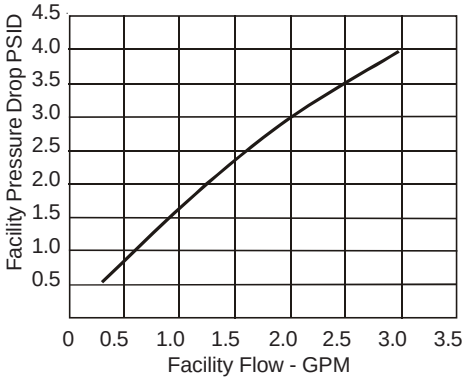
Figure 3-3 Plumbing Connections, Water-cooled Units

Facility Water Maximum Inlet Pressure must not exceed 150 PSIG.

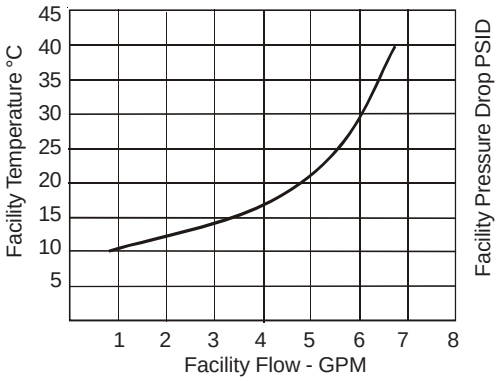
Facility Water Maximum Pressure Differential must not exceed 50 PSID under any condition.
(Pressure Differential = Inlet Pressure - Outlet Pressure)

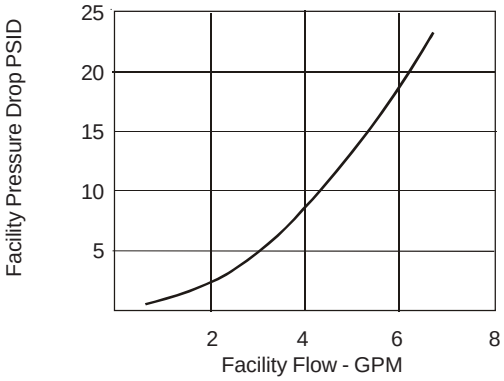
The facility water must meet the following conditions for the ThermoFlex 900 and ThermoFlex 1400 units to maintain its full rated capacity.





The facility water must meet the following conditions for the ThermoFlex 2500 units to maintain its full rated capacity.





Fluid Requirements

Never use flammable or corrosive fluids with this unit. Do not use automotive antifreeze. Commercial antifreeze contains silicates that can damage the pump seals. Use of automotive antifreeze will void the manufacturer's warranty. ▲

Acceptable fluids are:

- Filtered/Single Distilled water
- 0 - 95% Ethylene Glycol/Water
- 0 - 95% Propylene Glycol/Water
- Deionized water (1 - 3 MOhmcm, compensated)

Check the fluid concentration on a regular basis. Changes in concentration can impact system performance.

Before using any fluid or performing maintenance where contact with the fluid is likely refer to the manufacturer's MSDS for handling precautions. ▲

Ethylene glycol (EG) is hygroscopic, it will absorb water from its environment. This can affect the freezing point and boiling point of the fluid over time. This may result in system failure. ▲

When using EG/water or PG/water, top-off with EG/water or PG/water. Do not top-off with plain water. Topping-off with plain water can severely affect the freezing point and boiling point of the fluid. This may result in system failure. ▲

Do not use a Deionization (DI) filter cartridge with Inhibited EG or Inhibited PG. A DI filter will remove inhibitors from the solution rendering the fluid ineffective against corrosion protection. Also, inhibitors increase fluid conductivity. ▲

Water Quality and Standards

Process Fluid	Permissible (PPM)	Desirable (PPM)
Microbiologicals		
(algae, bacteria, fungi)	0	0
Inorganic Chemicals		
Calcium	<25	<0.6
Chloride	<25	<10
Copper	<1.3	<1.0
0.020 ppm if fluid in contact with aluminum iron		
Iron	<0.3	<0.1
Lead	<0.015	0
Magnesium	<12	<0.1
Manganese	<0.05	<0.03
Nitrates\Nitrites	<10 as N	0
Potassium	<20	<0.3
Silicate	<25	<1.0
Sodium	<20	<0.3
Sulfate	<25	<1
Hardness	<17	<0.05
Total Dissolved Solids	<50	<10
Other Parameters		
pH	6.5-8.5	7-8
Resistivity	0.01*	0.05-0.1*

* MOhmcm (Compensated to 25°C)

Unfavorably high total ionized solids (TIS) can accelerate the rate of galvanic corrosion. These contaminants can function as electrolytes which increase the potential for galvanic cell corrosion and lead to localized corrosion such as pitting. Eventually, the pitting will become so extensive that refrigerant will leak into the water reservoir.

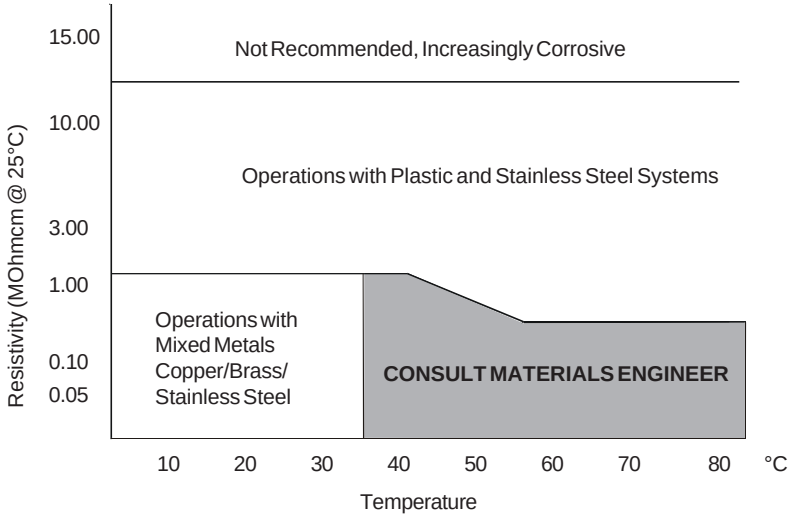
As an example, raw water in the United States averages 171 ppm (of NaCl). The recommended level for use in a water system is between 0.5 to 5.0 ppm (of NaCl).

Recommendation: Initially fill the tank with distilled or deionized water. Do not use untreated tap water as the total ionized solids level may be too high.

Although the initial fill may be as high as 10 MOhmcm (compensated to 25°C), the desired level for long time usage for units equipped with a deionization filter is 1 to 3 MOhmcm (compensated to 25°C).

The above two recommendations will reduce the electrolytic potential of the water and prevent or reduce the galvanic corrosion observed.

Water Quality/Materials Compatibility, units with in-line partial flow deionization filter



Facility Water	Permissible (PPM)	Desirable (PPM)
Microbiologicals		
(algae, bacteria, fungi)	0	0
Inorganic Chemicals		
Calcium	<40	<0.6
Chloride	<250	<25
Copper	<1.3	<1.0
0.020 ppm if fluid in contact with aluminum iron		
Iron	<0.3	<0.1
Lead	<0.015	0
Magnesium	<12	<0.1
Manganese	<0.05	<0.03
Nitrates\Nitrites	<10 as N	0
Potassium	<20	<0.3
Silicate	<25	<1.0
Sodium	<20	<0.3
Sulfate	<250	<50
Hardness	<17	<0.05
Total Dissolved Solids	<50	<10

NOTE A corrosion inhibitor is recommended if mixed metals are in the facility water loop. ▲

Water Treatment Kit

A Thermo Fisher Treatment Kit is available and is designed to minimize the effects of corrosion, scale, fouling, and microbial contamination. It allows the system to continue providing reliable service with optimal efficiency for the life of the unit.

The kit includes a biocide and corrosion inhibitor capable of treating up to ten gallons of application water and is designed to provide protection for a period of six months. This kit is designed to be compatible with the following fluids:

- Filtered/Singled Distilled Water
- Uninhibited Ethylene Glycol/Water
- Uninhibited Propylene/Water
- Deionized (DI) Water*
- Reverse Osmosis (RO) Water

*Thermo Fisher Water Treatment Kit is *not* intended to be used with A DI filtered system; the filter will remove a portion of the reagent's active ingredients limiting its effectiveness.

Compatibility with Recommended Fluids

Filtered/Singled Distilled water
This fluid is recommended primarily because it has all microorganisms that cause biological fouling removed through vaporizing and condensing the water. However, distilled water does not remain pure for very long when exposed to the atmosphere. Air-born spores can contaminate the water and activate algae growth. An effective maintenance plan would include switching out the fluid with newly distilled water every six months. The particulates that have been filtered out in the process are also preventive in keeping the system "clean" of contaminants.

NOTE Distilling water that contains an additive could increase the concentration of that additive in the water. ▲

Uninhibited Ethylene Glycol/Water
Ethylene glycol is used to depress the freezing point of water as a coolant. We recommend not using the uninhibited (no corrosion additives) ethylene glycol. It is more corrosive to copper than plain water so it is not recommended unless required for the application.

Inhibited Ethylene Glycol/ Water
Inhibited glycol can be used to increase the operating temperature range of the fluid but should not be used as a "pre-mixed anticorrosive" solution. Industry standards use a pH standard of 8 to determine when the fluid has become corrosive. Dowtherm® is an ethylene based product that contains dipotassium phosphates in a 4% concentration. The recommended use of Dowtherm® is mixing with distilled or deionized water or water that contains less than 25 ppm chloride and sulfate and less than 100 ppm total hardness of CACO3. The general term, inhibited glycol/water, is too close to meaning inhibited water. Inhibited water can have many types of additives including chromate that will quickly foul the cooling system. Some inhibitor additives can release the bonding agent in the carbon graphite in the PD2 pumps so they are incompatible, such as Sodium Hydroxide.

Uninhibited Propylene Glycol/Water
Although the use of propylene glycol is similar to ethylene glycol, propylene glycol is considered "safe" to use in the food industry. Propylene is less dense than ethylene and will have a tendency to weep through mechanical seals.

Inhibited Propylene Glycol/Water
Same issues as with uninhibited propylene and inhibited ethylene glycol.

Deionized Water (1-3 MOhmcm, compensated)
Deionized water has had the conductive ions that cause galvanic corrosion between dissimilar metals removed.
NOTE: This is not the normal state of water, so if it is too pure deionized water is aggressive to metal. The result is the leaching of metallic ions from metal surfaces which causes pitting.

NEVER use flammable or corrosive fluids with this unit. Do not use automotive antifreeze. Commercial antifreeze contains silicates that can damage the pump seals. Use of automotive antifreeze will void the manufacturer's warranty. ▲

Filling Requirements

Ensure the reservoir drain plug on the back of the unit is in place and that all plumbing connections are secure.

Before using any fluid refer to the manufacturer's MSDS for handling precautions. ▲

Locate and remove the reservoir cap by unscrewing it counterclockwise.

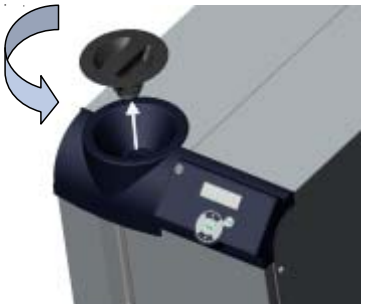


Figure 3-4 Reservoir Cap

Units should be filled with the reservoir bag filter in place to prevent the introduction of particulates into the system. Units are shipped with a bag filter in place. For information on changing the bag filter, see Section VI.

The polyethylene reservoir has a sight tube and ball for easy fluid level monitoring. *Slowly* fill the reservoir with clean process fluid through the funnel only, failure to comply may result in internal spillage.

NOTE Be careful not to fill the reservoir above MAX LEVEL fill line. This will result in a unit over flow error (O FLO)causing the unit to shut down. ▲

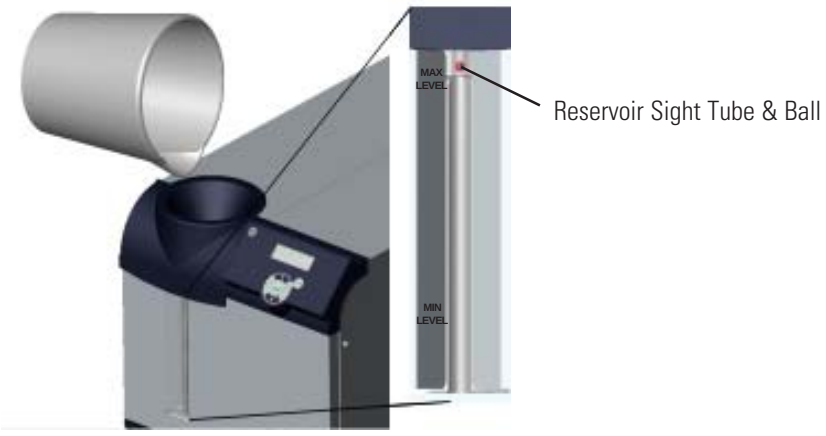


Figure 3-5 Reservoir Sight Tube & Ball

Since the reservoir capacity may be small compared to your application and air may need to be purged from the lines, have extra cooling fluid on hand to keep the system topped off when external circulation is started.

Replace the reservoir cap by screwing it clockwise. Cap should be hand tight.

Section IV Operation

Basic Controller

The controller controls temperature using a Proportional-Integral-Derivative (PID) algorithm. It is designed with self-diagnostic features and an easy to use operator interface.

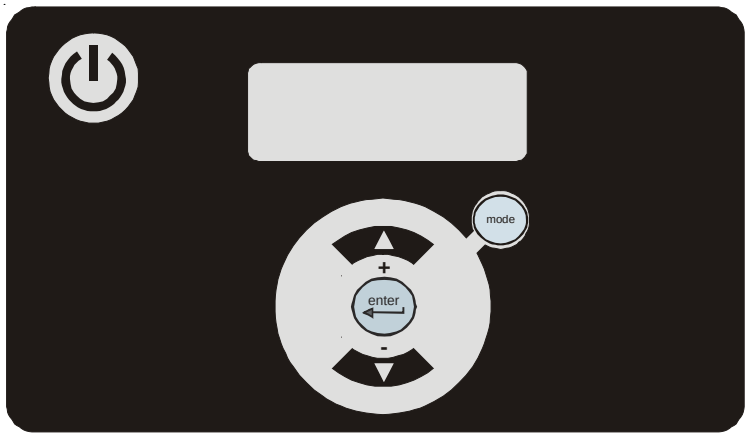


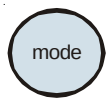
Figure 4-1 Basic Controller

This key is used to start and stop the unit.

This key is used to navigate through the controller displays and to increase adjustable values.

This key is used to navigate through the controller displays and to decrease adjustable values.

This key has two functions. Pressing it once allows changes to be made, pressing it again after the changes are made allows you to continue to other displays.



This key is also used to navigate through the controller loops.

Setup

NOTE For first time use, please refer to the quick start instructions included with your unit or the copy in this manual. The manual's version follows the Table of Contents. ▲

Before starting the unit, double check all electrical and plumbing connections. Have extra recirculating fluid on hand. If the unit will not start refer to Section VII Troubleshooting.

Start Up

- Place the circuit protector located on the rear of the unit to the on (**I**) position. The display will indicate a series of upward scrolling bars ( ) .
- The bars will scroll upward indicating the controller is initializing the unit. The initialization takes approximately 15 seconds.
- When the bars disappear the controller display will go blank.
- Press the key on the controller. The display will show the process fluid temperature. The pump and refrigeration system will also start.

If the auto restart is enabled and the unit shuts down as a result of a power failure, when power is restored the unit will automatically restart. Auto restart is enabled using the Setup Loop, see Setup Loop in this Section. ▲

NOTE After initial start up, check your plumbing for leaks. ▲

If desired, press the key to display the pump's discharge pressure - **P1**. The display will alternate between **P1** and the pump's discharge pressure value.

If the unit is equipped with an optional flow transducer, pressing the key again will display the flow rate - **FLo**. The display will alternate between **FLo** and the flow rate value.

Press the key again to display the process fluid temperature.

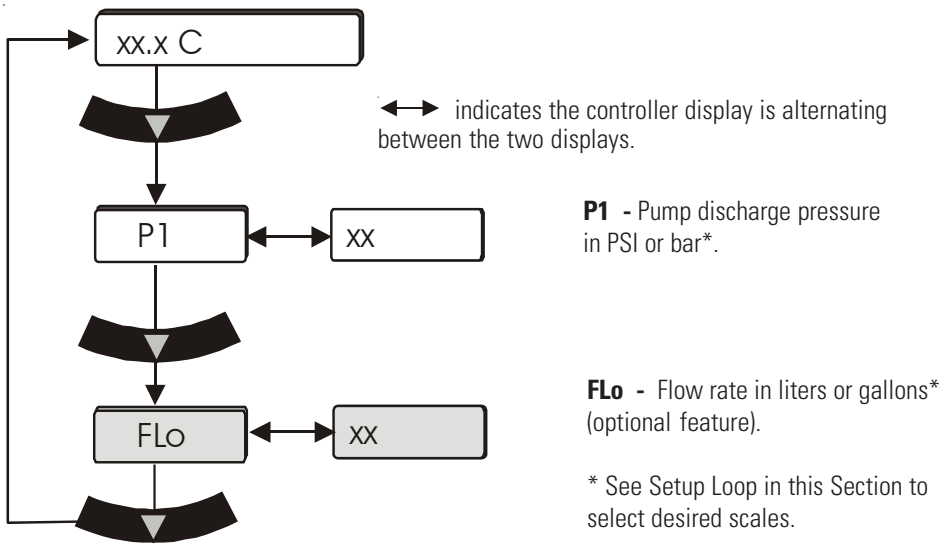


Figure 4-2 Main Loop

Controller Loops

The controller has the capability to display various loops which indicate operating conditions and parameters within the unit. The loops are selected and changed by pressing the appropriate keys.

When the controller is first powered up it goes through a short initialization and then displays the process fluid temperature. Use the key combination shown below to scroll through the loops.

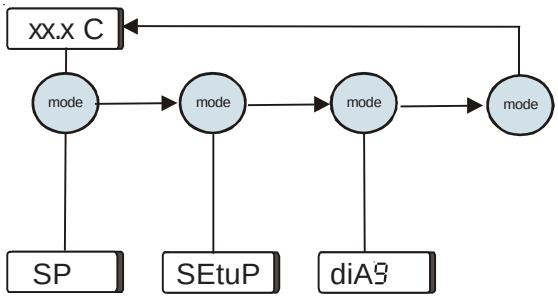


Figure 4-3 Controller Loops (Unit running)

SP is the Setpoint Loop and is used to display and change the setpoint. The setpoint is the desired process fluid temperature needed for your application. The Setpoint Loop is accessed by pressing the **mode** key, see next page.

SEtuP is the Setup Loop. The Setup Loop allows you to display and/or alter different parameters of the controller. The Setup Loop is accessed from the Setpoint Loop by pressing the **mode** key.

diA is the Diagnostic Loop. The Diagnostic Loop allows you to display the operating times for various components within the unit. The Diagnostic Loop is accessed from the Setup Loop by pressing the **mode** key.

NOTE The loops can be accessed and changed without the unit running as long as the circuit protector is in the on (**I**) position. ▲

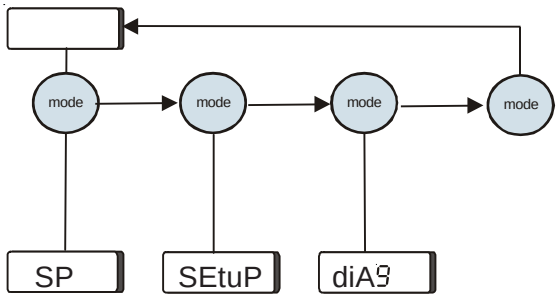


Figure 4-4 Controller Loops (Unit not running)

Setpoint Loop (SP)

- Ensure the controller is either a blank screen (not yet initialized) or displaying the process fluid temperature.
- Press the mode key and the controller display will alternate between **SP** and the setpoint value.
- If no change is required press the enter key to return the display to the process fluid temperature.
- If a setpoint change is required, use the keys.

  The setpoint range is +5°C to +40°C.

NOTE If the keys are not used within one minute the controller will time out and return to the process fluid temperature display and any changes will not be accepted. ▲

- Once the desired value is displayed press the enter key to confirm the change.

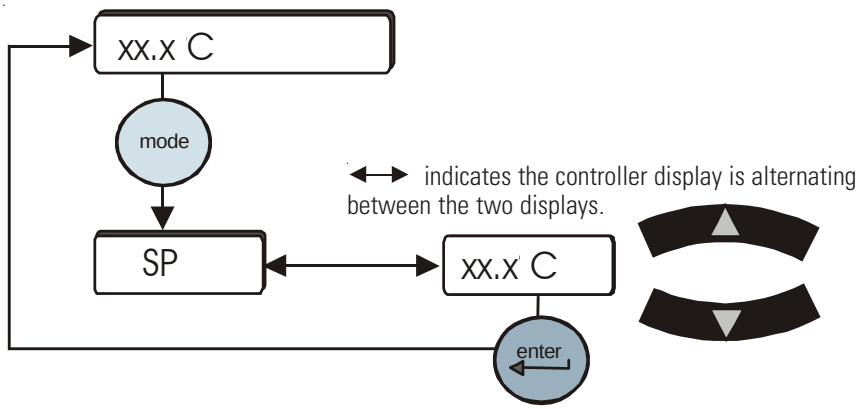


Figure 4-5 Setpoint Loop

Setup Loop (SEtuP)

Use the Setup Loop to adjust/verify the following controller settings.

- Scales: °C or °F, Liters or Gallons, PSI or Bar
- High and low temperature alarm limits 30C / 12C
- High and low pump discharge pressure alarm limits and time delays 6.89 2s 1.00 10s
- Fault reaction to a temperature, pressure or flow (optional) alarm limit (continue to run or shut down)
- Audible alarm enabled/disabled
- Auto restart feature enabled/disabled
- Preventive care cleaning frequency reminder for air and fluid filters

Optional Features:

- Auto refill alarm
- DI filter cartridge preventive maintenance interval
- High/low flow alarm limits 12.5 2.0
- Analog I/O feature enabled/disabled
- Serial communications feature enabled/disabled
- Anti drainback valve position
- **Save/abort all changes**

To enter the Setup Loop ensure the controller display is either a blank screen (unit off) or displaying the process fluid temperature. Press the key and the display will indicate **SP**, press it again to display **SEtuP**.

Press the 

key to continue, or press 

twice to return to the process fluid temperature or blank display.

Use the  key to sequence down through the loop. Use the  key to sequence back up through the loop.

To change any parameter:

- Press the 

key.
- Use the  keys to change a displayed value.
- Press 

key to confirm the change.

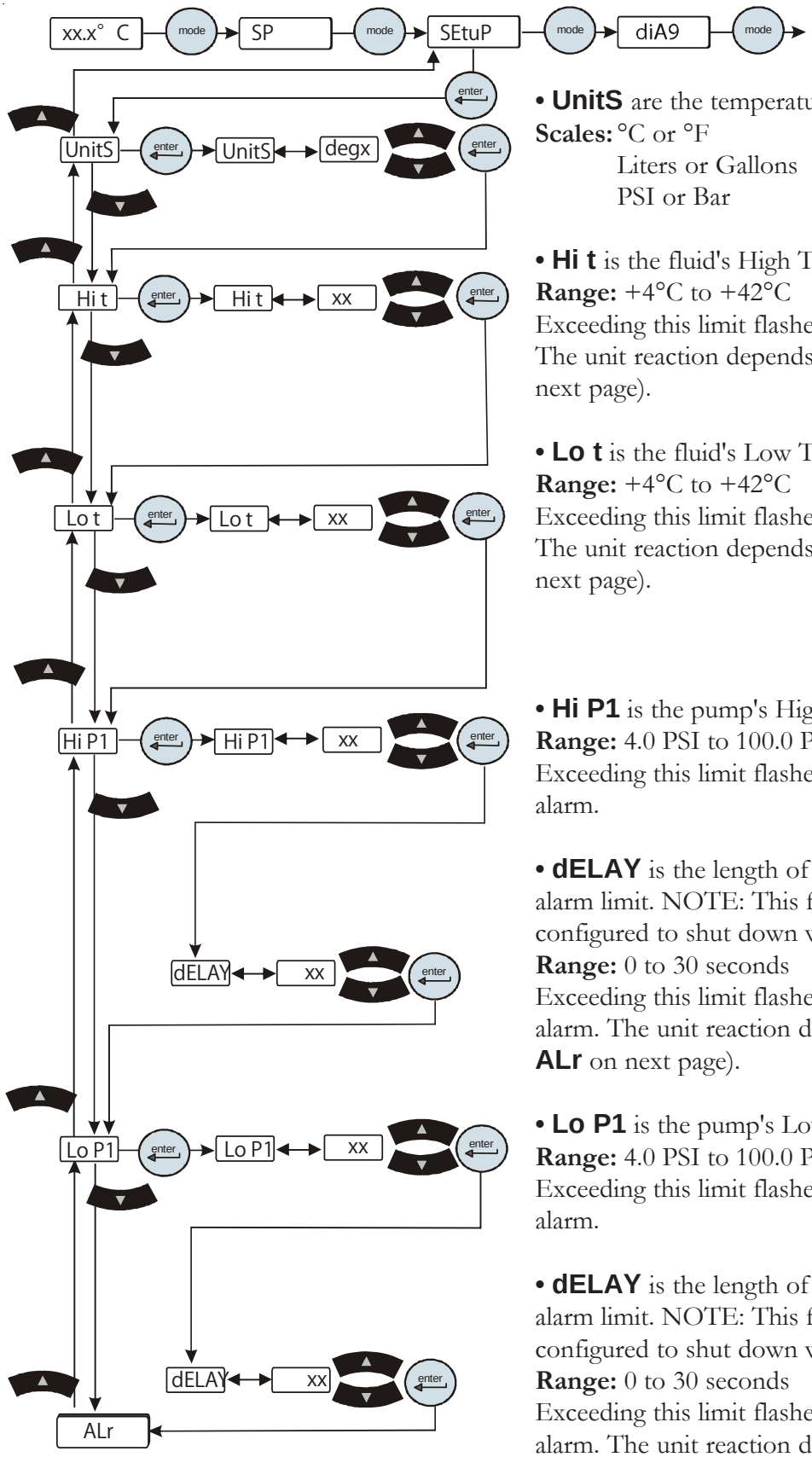


Figure 4-6 Setup Loop (All Units)

• **UnitS** are the temperature, fluid flow and pressure display scales.

Scales:		**Defaults:**	
	°C or °F		°C
	Liters or Gallons		Liters
	PSI or Bar		PSI

• **Hi t** is the fluid's High Temperature alarm limit.
Range: +4°C to +42°C **Default:** +42°C
Exceeding this limit flashes **Hi t** and, if enabled, sounds the alarm. The unit reaction depends on the alarm configuration (see **ALr** on next page).

• **Lo t** is the fluid's Low Temperature alarm limit.
Range: +4°C to +42°C **Default:** +4°C
Exceeding this limit flashes **Lo t** and, if enabled, sounds the alarm. The unit reaction depends on the alarm configuration (see **ALr** on next page).

• **Hi P1** is the pump's High Pressure discharge alarm limit.
Range: 4.0 PSI to 100.0 PSI **Default:** 100.0 PSI
Exceeding this limit flashes **Hi P1** and, if enabled, sounds the alarm.

• **dELAY** is the length of time the pump can exceed the Hi P1 alarm limit. NOTE: This feature is active only if the unit is configured to shut down with a pressure alarm.
Range: 0 to 30 seconds **Default:** 0 seconds
Exceeding this limit flashes **Hi P1** and, if enabled, sounds the alarm. The unit reaction depends on the alarm configuration (see **ALr** on next page).

• **Lo P1** is the pump's Low Pressure discharge alarm limit.
Range: 4.0 PSI to 100.0 PSI **Default:** 4.0 PSI
Exceeding this limit flashes **Lo P1** and, if enabled, sounds the alarm.

• **dELAY** is the length of time the pump can exceed the Lo P1 alarm limit. NOTE: This feature is active only if the unit is configured to shut down with a pressure alarm.
Range: 0 to 30 seconds **Default:** 10 seconds
Exceeding this limit flashes **Lo P1** and, if enabled, sounds the alarm. The unit reaction depends on the alarm configuration (see **ALr** on next page).

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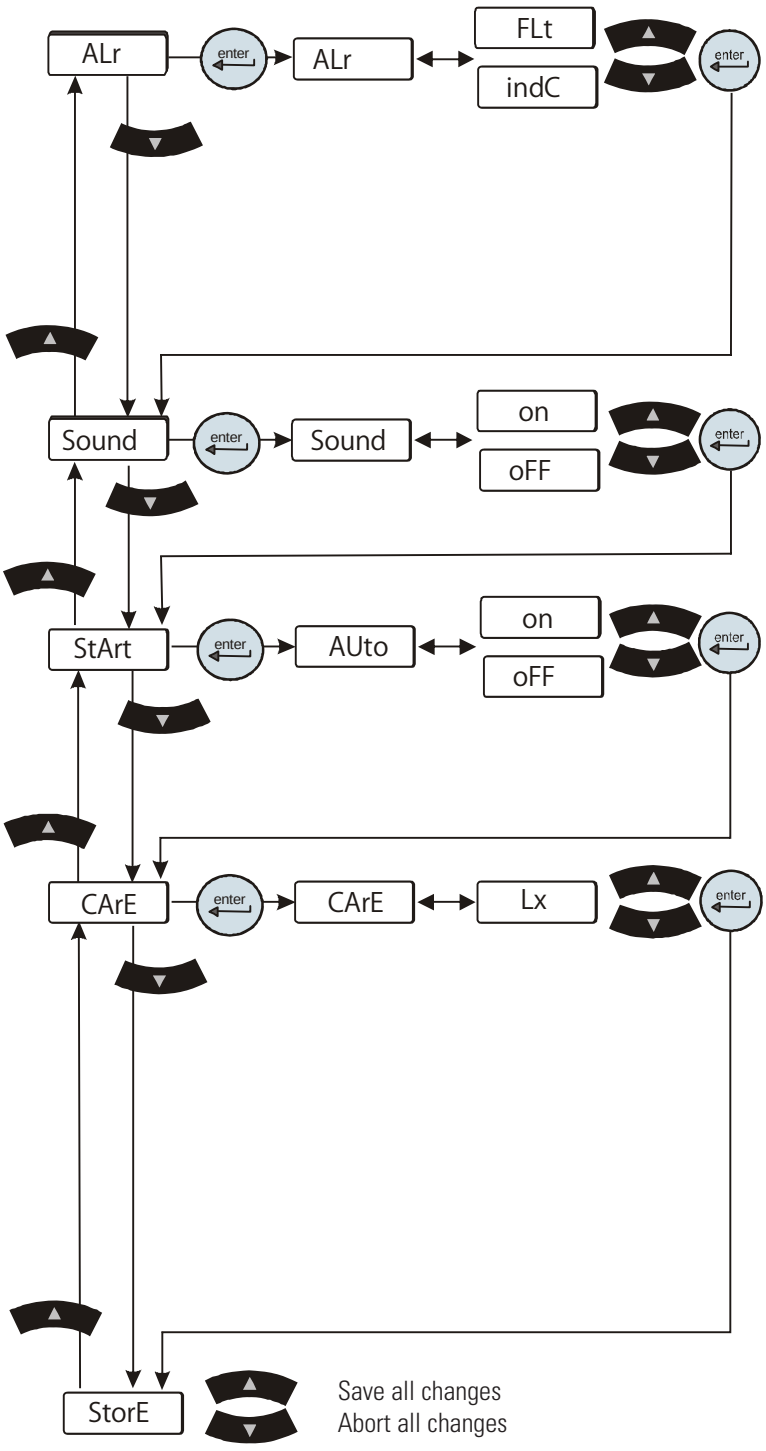


Figure 4-6 Setup Loop (All Units)

• **ALr** is used to configure the unit's reaction for exceeding an alarm limit (temperature, pressure and flow (optional). The selected configuration will apply to all the alarms. The unit will either shut down (**FLt**) or continue to run (**indC**). In each configuration, the controller will display the error code and sound the audible alarm, if enabled.
Range: FLt or indC **Default:** FLt

• **Sound** is used to turn the audible alarm on or off.
Range: on or off **Default:** on

• **StArt** is used to enable/disable the auto restart.
Range: on or off **Default:** off

• **CArE** is used to set the preventive care cleaning frequency reminder for the unit's air and fluid filters, in hours. The time selected is based on your operating environment, see Section VI.
Range: L1 (1000 hours) **Default:** L1
L2 (2000 hours)
L3 (3000 hours)

Exceeding this limit flashes **FLtrS,** see Section VI.

NOTE If your unit is equipped with any of the **Optional Features** refer to the next page. ▲

When the display indicates **StorE** press ▲ to save *all* changes or press ▼ to abort *all* changes. The display will return either the process fluid temperature or, if the unit was off when you entered the loop, a blank screen.

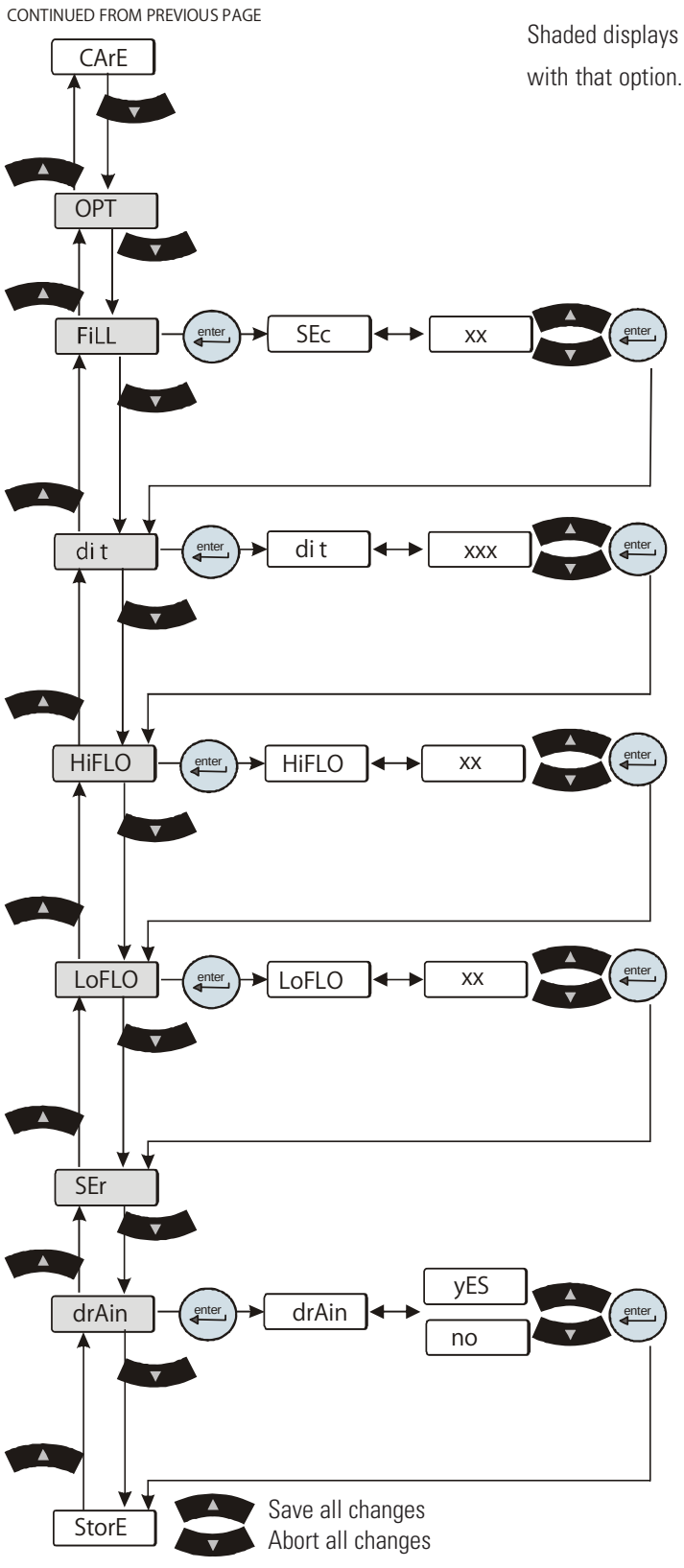


Figure 4-7 Setup Loop (Optional Features)

• **OPt** is used to configure the analog in/out mode of operation. See Appendix C.

• **FiLL** is used to set the time limit the auto refill has for filling the unit's reservoir to the normal operating level.
Range: 0 to 900 seconds **Default:** 45 seconds
Exceeding the time limit flashes **rEFiL** and the auto refill will shut down.

• **di t** is used to set the preventive care cleaning frequency reminder for the unit's DI filter cartridge.
Range: 0 to 9999 hours **Default:** 448 hours
Exceeding the limit flashes **Di,** see Section VI.

• **HiFLO** is used to set the high flow alarm limit.
Range: 0.5 to 5.0 GPM **Default:** 5.0 GPM
Exceeding this limit flashes **HiFLO** and, if enabled, sounds the alarm. The unit's reaction depends on the alarm (**ALr**) setting.

• **LoFLO** is used to set the low flow alarm limit.
Range: 0.5 to 5.0 GPM **Default:** 0.5 GPM
Exceeding this limit flashes **LoFLO** and, if enabled, sounds the alarm. The unit's reaction depends on the alarm (**ALr**) setting.

• **SEr** is used to configure the serial communications mode of operation. See Appendix D.

• **drAin** is used to open and close the unit's anti drainback valve for draining, see Section V.
Range: yes or no
Default: no

NOTE The valve automatically closes when you exit the **drAin** display. ▲

When the display indicates **StorE** press ▲ to save *all* changes or press ▼ to abort *all* changes. The display will return either the process fluid temperature or, if the unit was off when you entered the loop, a blank screen.

Diagnostic Loop (di A9)

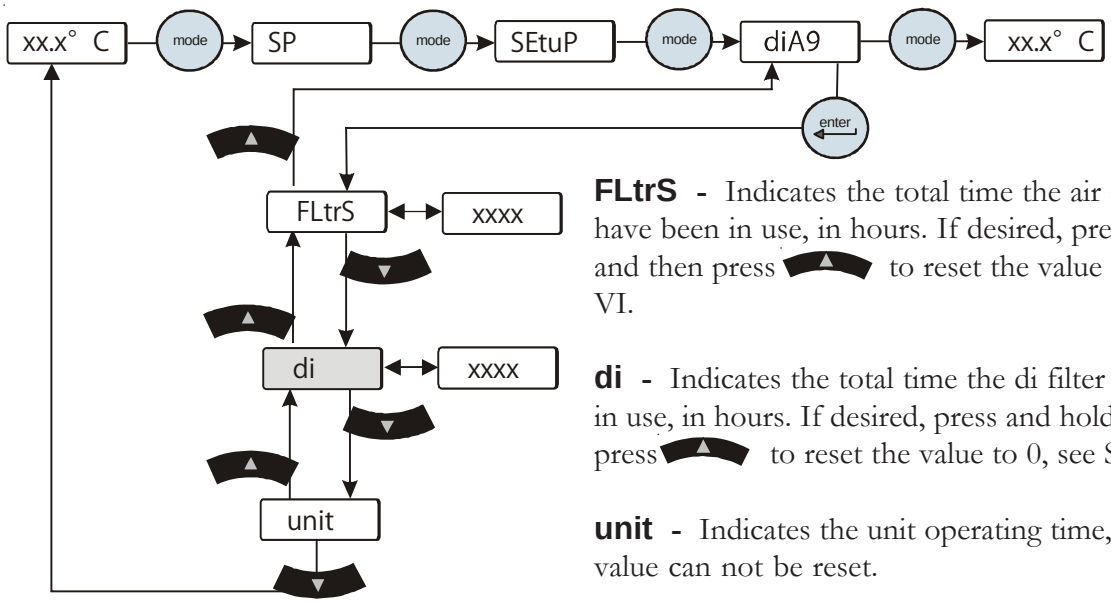
The Diagnostic Loop is used to view or reset the operating times of various unit components.

To enter the Diagnostic Loop ensure the controller display is either a blank screen (unit off) or displaying the process fluid temperature.

Press the mode key and the display will indicate **SP**, press mode again to display **SEtuP**, press mode again to display **diA** .

Press enter to enter the loop or press mode to return to the process fluid temperature or blank display.

Use the ▼ key to sequence down through the loop. Use the ▲ key to sequence up through the loop.



FLtrS - Indicates the total time the air and fluid filters have been in use, in hours. If desired, press and hold enter and then press ▲ to reset the value to 0, see Section VI.

di - Indicates the total time the di filter cartridge has been in use, in hours. If desired, press and hold enter and then press ▲ to reset the value to 0, see Section VI.

unit - Indicates the unit operating time, in hours. This value can not be reset.

Figure 4-8 Diagnostic Loop

Shut Down

Press the  key on the controller.

NOTE To protect the unit's compressor, the unit will enter a 20 second shut down cycle before the refrigeration system and pump shut down. During this time the display will indicate OFF. The bars will scroll downward indicating the controller is in the shut down cycle. ▲

When the display goes blank it is safe to place the circuit protector located on the rear of the unit to the off (**0**) position.

Using any other means to shut the unit down can reduce the life of the compressor.

Always turn the unit off and disconnect it from its supply voltage before moving the unit. ▲

The circuit protector located on the rear of the unit is not intended to be used as a disconnecting means. ▲

Section V Options/Accessories

Auto Refill

The Auto Refill provides makeup fluid to replace any fluid lost to evaporation, etc. It requires a pressurized fluid source connection to the ¼" Female Pipe Thread fitting on the rear of the unit.

Figure 5-1 Auto Refill Fitting

The auto refill fluid must also meet water quality standards or the valve may fail to operate as designed, see Section III.

The auto refill valve input pressure must be < 80 PSI to ensure the valve functions properly.

The auto refill operates when all of the following conditions are met:

- Fluid is available
- The unit is turned on
- The fluid reaches a low level condition.

The auto refill shuts off when:

- The fluid reaches the correct operating level.

Internal DI Cartridge

A partial flow DI filter cartridge is designed to provide between 1 and 3 MOhmcm water resistivity.

NOTE The Puralite sensor that comes with the DI cartridge requires a separate power source. ▲

Do not use a Deionization (DI) filter cartridge with Inhibited EG or Inhibited PG. A DI filter will remove inhibitors from the solution rendering the fluid ineffective against corrosion protection. Also, inhibitors increase fluid conductivity. ▲

Remove the two thumbscrews securing th DI access panel to the top of the unit. If there is a cartridge in place, first undo the hose fitting by pressing on the quick disconnect located on the top white connection.

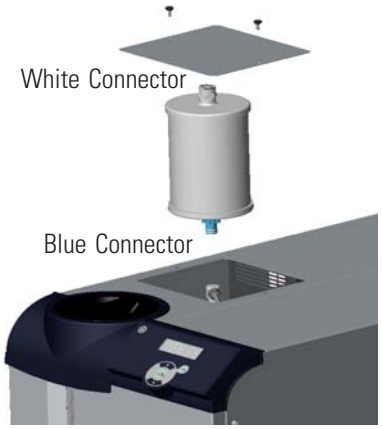


Figure 5-2 Internal DI Cartridge

The DI Cartridge will overpressure if it is removed from the unit before removing the hose fitting. ▲

Next rotate the cartridge ¼ turn counterclockwise to remove it.

Remove the new cartridge from the shipping bag. The cartridge has a blue and a white connector. Lower the cartridge into the unit with the blue connector facing downward. Press down on the cartridge lightly to engage and then rotate it ¼ turn clockwise or until you feel the filter clock into place.

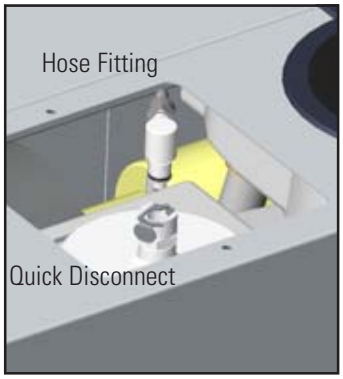


Figure 5-3 DI Fittings

Push the hose fitting into the quick disconnect located on the white end of the cartridge.

Replace the access panel and thumbscrews.

The Puralite sensor on the back of the unit turns red when the cartridge needs changing.

NOTE The cartridge can be changed with the unit running, however, since the cartridge runs in a parallel arrangement, disconnecting the cartridge adds an additional 0.5 GPM to the main flow (for PD pumps). The additional flow will cause an increase in system pressure which may cause a high fluid pressure fault. ▲

External DI Cartridge

A partial flow DI filter cartridge is designed to provide between 1 and 3 MOhmcm water resistivity.

NOTE: The Puralite sensor that comes with the DI cartridge requires a separate power source. ▲

Do not use a Deionization (DI) filter cartridge with Inhibited EG or Inhibited PG. A DI filter will remove inhibitors from the solution rendering the fluid ineffective against corrosion protection. Also, inhibitors increase fluid conductivity. ▲

If there is a cartridge in place, first undo the hose fitting by pressing on the quick disconnect located on the top white connection.

Figure 5-4 External DI Cartridge

The DI Cartridge will overpressure if it is removed from the unit before removing the hose fitting. ▲

Remove the new cartridge from the shipping bag. The cartridge has a blue and a white connector. Lower the cartridge into the bracket with the blue connector facing downward. Press down on the cartridge lightly to engage and then rotate it ¼ turn clockwise or until you feel the filter click into place.

Push the hose fitting into the quick disconnect located on the white end of the cartridge.

The Puralite sensor turns red when the cartridge needs changing.

NOTE The cartridge can be changed with the unit running, however, since the cartridge runs in a parallel arrangement, disconnecting the cartridge adds an additional 0.5 GPM to the main flow (for PD pumps). The additional flow will cause an increase in system pressure which may cause a high fluid pressure fault. ▲

Internal Pressure Relief Valve

The pressure relief valve, located on the top left rear of the unit, is used to set the desired system back pressure to your application. The valve is factory preset to 80 ± 5 psi (550 ± 1 kPa).

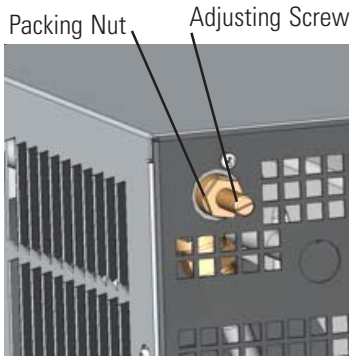


Figure 5-5 Nut and Screw

If the unit is not plumbed to an application, set the pressure by installing a loop of hose equipped with a shut-off valve between the supply and return fittings. Start the unit and allow it to prime, then close the valve.

Use the controller's  to display P1, it should display 80 ± 5 psi.

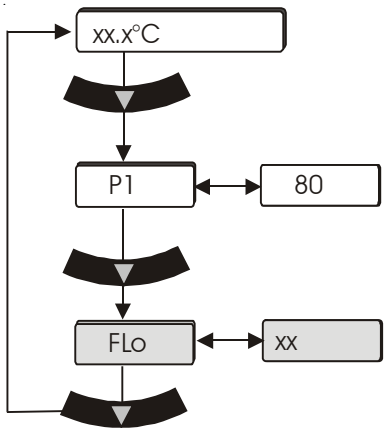


Figure 5-6 Main Loop

Use a screwdriver to turn the adjusting screw (counterclockwise to reduce pressure) until the controller displays the desired setting.

NOTE Due to internal back pressure, the minimum pressure setting for a deadheaded pump is 32 psi for a PD 2 pump, and 8 psi for a PD 1 (these settings prohibit external flow from the unit). ▲

If the unit is plumbed to an application, ensure the unit is off. Then back out the adjusting screw counterclockwise to reduce pressure. Turn the unit on. Ensure that there is back pressure in the system. Turn the adjusting screw until the controller displays the desired setting.

Do not exceed 100 psi. ▲

When complete, inspect the area around the $^{5}/_{8}$" packing nut for fluid. If fluid is present, slightly tighten the nut and reinspect.

NOTE Should the unit start to vibrate the valve setting may be the cause. Changing the pressure setting ± 5 psi will eliminate the vibration. ▲

External Pressure Relief Valve

The pressure relief valve is used to set the desired system back pressure (P1) to your application. The valve is factory preset to 80 ± 5 psi (550 ± 1 kPa).

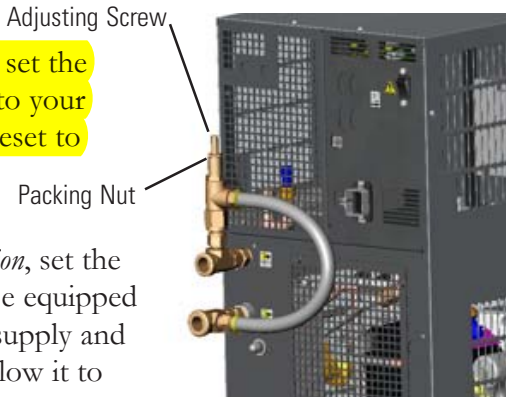


Figure 5-7 Nut and Screw

If the unit is not plumbed to an application, set the pressure by installing a loop of hose equipped with a shut-off valve between the supply and return fittings. Start the unit and allow it to prime, then close the valve.

Use the controller's  to display P1, it should display 80 ± 5 psi.

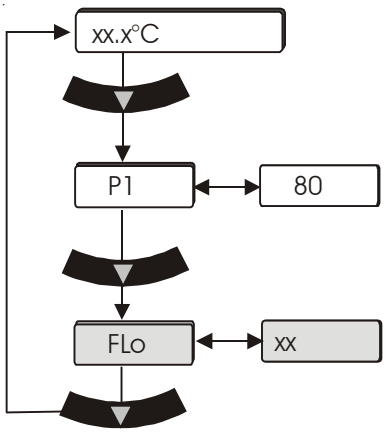


Figure 5-8 Main Loop

Use a screwdriver to turn the adjusting screw (counterclockwise to reduce pressure) until the controller displays the desired setting.

NOTE Due to internal back pressure, the minimum pressure setting for a deadheaded pump is 40 psi for a PD 2 pump, and 22 psi for a PD 1 (these settings prohibit external flow from the unit). ▲

If the unit is plumbed to an application, ensure the unit is off. Then back out the adjusting screw counterclockwise to reduce pressure. Turn the unit on. Ensure that there is back pressure in the system. Turn the adjusting screw until the controller displays the desired setting.

Do not exceed 100 psi. ▲

When complete, inspect the area around the $^{5}/_{8}$" packing nut for fluid. If fluid is present, slightly tighten the nut and reinspect.

Flow Control

Flow control is achieved using a 3-way valve plumbed to the auxiliary port on the rear of the unit.

Press the controller's down arrow twice to display the controller's **FLo** display, see previous page. Turn the valve handle until the desired rate is displayed.

NOTE The valve is sensitive to slight adjustments. ▲

Figure 5-9 Flow Control

Pressure Control with Flow Readout

The Pressure Control with Flow Readout works just like the Pressure Relief Valve discussed on the previous page. It allows you to control the pressure going to your application.

This valve is plumbed into the unit's auxiliary port, allowing you to also monitor the flow rate to your application using the controller's **FLo** display, see previous page.

Figure 5-10 Pressure Control

Anti Drainback

Units installed below the end-user application may allow system fluid to drain back into the chiller and cause spillage. The anti-drainback valve is designed to prevent any such spillage.

The valve automatically closes anytime the unit is powered down or if the pump shuts down.

This option is required if your unit is more than 24 feet below your application, or if there is a possibility of flood back due to the occasional opening of the process lines for either application swaps or unit servicing. See Section VIII for additional draining information.

SEMI

Emergency Off (EMO)

A guarded red mushroom shaped push-button switch with twist-to-reset is provided in the front of the unit to turn off the unit in case of an emergency. The button head is engraved with "EMO" in large white filled letters.

NOTE The EMO is controlled by a safety circuit and is not influenced by the unit's firmware/software. ▲

Activation of the EMO button will remove power from the main contactor coil stopping operation of the unit. The controller will display **Er 48**.

Resetting the EMO button will not restart the unit. After all hazards have been removed and the EMO is reset, the unit must be reset by pushing the RESET button on the control panel. In the local mode, the unit will restart by pressing the START STOP button again. In the serial communications mode, send the appropriate start command. In the analog/digital I/O mode, cycle the on/off input.

Lockout/Tagout (LOTO)

Before performing Chiller maintenance, the energy sources associated with the Chiller system must be lockout and tagged out (LOTO). Hazard control features added to the system (e.g., safety interlocks, EMO) are not a substitute for turning off and locking out electrical or fluid energy.

For units rated 20 Amps or less, electrical LOTO is accomplished by removing the power cord and closing the locking device on the power receptacle located on the rear of the unit. For other units, electrical LOTO is the responsibility of the user and can be provided by:

- Using the main disconnect (knife switch at system control cabinet).
- Disconnecting main power at the facility power source prior to the system controller cabinet.
- In addition, follow all OSHA and local facility LOTO directives.

Drip Pan and Drain

The unit is equipped with a secondary containment (drip pan) in case there is a leak.

The drip pan drain located on the rear of the unit has a ¾" FPT fitting. The unit is shipped with a ¾" NPT plug installed on the drain. Since the pan will not hold more than 110% of the reservoir volume, remove the

plug and connect the drain to guide the fluid to an appropriate spillage location.

Seismic Tie-Downs
Seismic tie-downs are installed on the unit. It is the user's responsibility to secure the unit using the attached tie downs.

Ground Fault Current Interrupter
An electrical safety device which opens a circuit upon observation of electricity leaking to ground through an undefined path, most likely a human being.

Center of Gravity (± ½", PD 2 pump, standard unit, no fluid in tank)

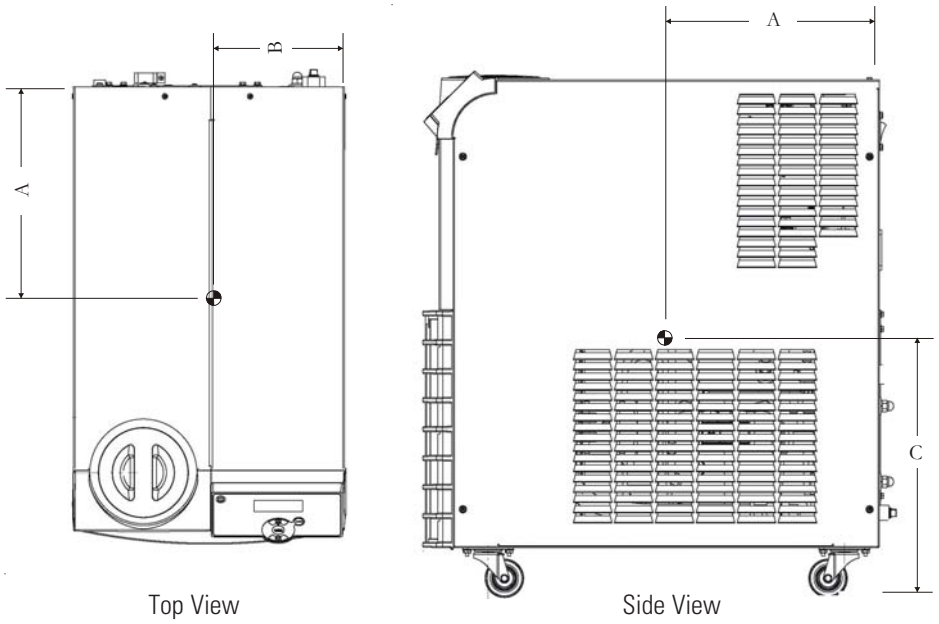


Figure 5-11 Center of Gravity

	ThermoFlex 900/1400		ThermoFlex 2500	
A	10 ¾ "	27.3 cm	12"	30.5 cm
B	6 ¾ "	17.2 cm	8 ⅜"	21.3 cm
C	13 ½"	34.3 cm	13 ½"	34.3 cm

Other Options

There are many other options that can be added to your system that can improve its performance in your application. Please contact Thermo Fisher Scientific's Sales, Service and Customer Support to assist you with questions that you may have regarding upgrading your ThermoFlex, see inside cover for contact information.

Other Accessories

Installation kit - includes replacement air and fluid filters

Maintenance kit - includes a set of hoses, adaptor fittings and Teflon® tape

Fluids

Fluid treatment kit

Please contact Thermo Fisher Scientific's Sales, Service and Customer Support to assist you with questions that you may have regarding accessories for your ThermoFlex, see inside front cover for contact information.

Section VI Preventive Maintenance

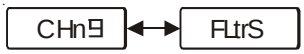
Preventive Maintenance Timer (CArE)

The ThermoFlex chiller has an integrated preventive maintenance timer that will alert you when it is time to perform preventive maintenance. This unique feature will remind you to change your air and fluid filters.

Based on the environment in which your chiller is located, you can choose from three levels of preventive maintenance L1, L2, and L3:

- L1 – 1,000 hours - default setting
  - · Heavy manufacturing environment
  - · Airborne particulate created during manufacturing process
- L2 – 2,000 hours
  - · Typical production environment
- L3 – 3,000 hours
  - · Clean environment – filtered air
  - · Typically laboratory or research environment

This parameter can be changed/set using the Setup Loop, see Section IV. When the unit exceeds the chosen limit, the controller will flash



and (if enabled) an audible alarm will sound.

To clear this message press 

. This will automatically restart the preventive maintenance timer for your filters. Each time the unit exceeds the chosen time, the controller will remind you that it is time to change your filters.

If you change your filters before the preventive timer trips, you can clear the timer by using the Diagnostic Loop, see Section IV.

NOTE For air-cooled units both the air and fluid filters in the ThermoFlex can be changed while the unit is running. For water-cooled units only the fluid filter can be changed while the unit is running. ▲

Fluid Filter Bag

The reservoir has a fluid bag filter designed to prevent the introduction of particulates into the system. Units are shipped with a bag filter in place.

NOTE The fluid bag filter can be removed with the unit operating. ▲

Before using any fluid or performing maintenance where contact with the fluid is likely refer to the manufacturer's MSDS for handling precautions. ▲

When it is time to replace the bag, gently pull up on the plastic funnel housing to remove it and simply pull the bag out of the unit. Replacement bags are available from Thermo Fisher Scientific.

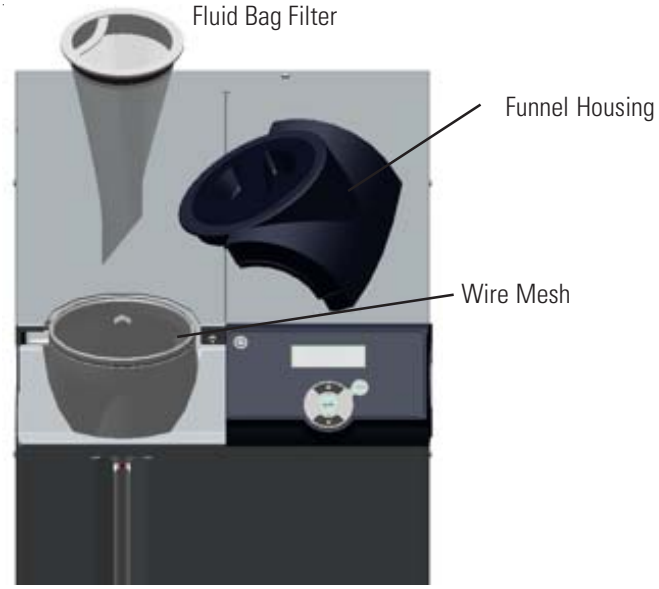


Figure 6-1 Fluid Filter Bag

When you remove the bag you will notice a wire mesh inside the reservoir supply line. The mesh is used to help streamline the flow into the reservoir. After several bag replacements turn the unit off and remove the mesh to inspect it for debris/damage.

The fluid velocity into the reservoir will rapidly increase with the mesh removed and cause splashing. The unit must be turned off before removing the mesh. This is especially critical when using ethylene or propylene glycol. ▲

NOTE To prevent particulates from entering the reservoir, ensure the fluid bag filter is in place before removing the mesh. ▲

Reservoir Cleaning

The user is responsible for maintaining reservoir fluid quality. The fluid should be checked on a regular interval. Start with frequent checks until a regular interval (based on your application) can be established.

If cleaning is necessary, flush the reservoir with a fluid compatible with the process fluid and the unit's wetted parts, see Section VIII.

Before using any fluid or performing maintenance where contact with the fluid is likely refer to the manufacturer's MSDS for handling precautions. ▲

Reservoir Sight Tube

The sight tube can be cleaned by gently pulling up on the plastic funnel housing to remove it (see illustration on previous page) and then gently pulling out the black sight ball stopper from the tube. Use a long soft-bristle ¼" brush. Caution must be used not to scratch the glass.

For easier replacement, wet the stopper first and then use a twisting motion to install it in the sight tube.

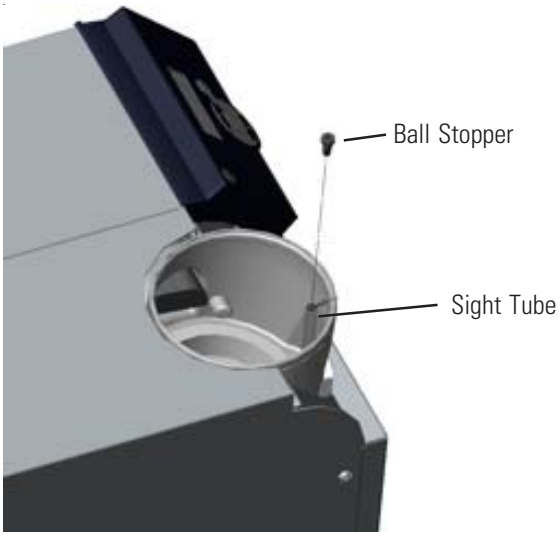


Figure 6-2 Reservoir Cleaning

Condenser Filter

The filter can be cleaned through the grille using a vacuum with a soft-bristle brush. When it is time for a more thorough cleaning the one-piece grille assembly can be removed. To remove it first pull the bottom of the assembly away from the unit and then pull it away from the top.

Failure to clean/replace the condenser filter will lead to a loss of cooling capacity and lead to premature failure of the cooling system. ▲

NOTE Water-cooled units have an embedded screw located at the top of the grille securing it to the unit. Loosen the screw to remove the grille. ▲

The condenser framing and fins located behind the grille assembly are very sharp. Use caution when removing the assembly. ▲

Water- cooled units also have a fan with sharp blades, ensure the unit is off before removing the assembly. ▲

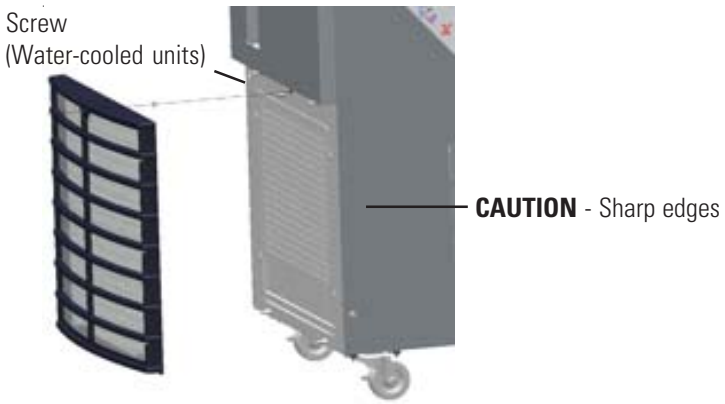


Figure 6-3 Screen Removal

Once removed, vacuum the filter with a soft-bristle brush or wash it Shake off as much of the excess water as possible before reinstalling.

To change the filter remove the three screws securing the filter to the grille assembly and then pull on the filter's plastic brace to remove it.

The easiest way to replace the filter is to bow it as shown below and slide one end under the tabs on the grille, then under the other end. Replace the screws. Press the grille back into place.

For water cooled units tighten the screw at the top of the grille.

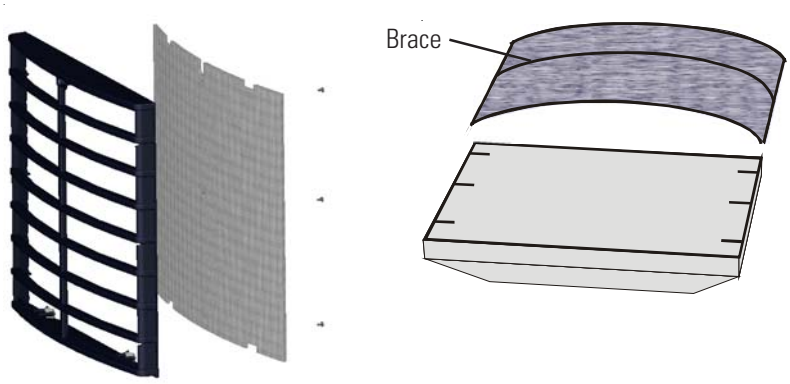


Figure 6-4 Condenser Filter

DI Filter (Optional)

A preventive maintenance schedule for the DI filter cartridge will need to be established based on your specific application.

A Puralite sensor is located on the back of your chiller. The sensor will illuminate red when it is time for the DI filter cartridge to be changed.

Figure 6-5 Puralite

The unit also has a *separate* integrated audible alarm that works independently of the Puralite. The alarm is based on unit run hours that will alert you when it is time to change your filter. This feature is especially helpful if the Puralite sensor is not readily accessible, see Setup Loop in Section IV.

If you already know how often your DI filter needs to be changed, you can input the number of hours into the Setup Loop's **di t** display, see Section IV. When your unit exceeds this time, the controller will flash **DI** and the audible alarm, if enabled, will sound.

To clear this message and stop the audible alarm press enter .

This will automatically restart the preventive maintenance timer for your DI filter. If you change the filter before the preventive maintenance timer alerts you, you can clear the timer by accessing the Diagnostic Loop **di** display see Section IV.

If you aren't sure how often to change your DI filter cartridge use the Setup Loop's default time of 448 hours. When alerted, check the Puralite sensor on the back of the unit to see if it is illuminated. If it is not illuminated reset the timer for another 448 hours by pressing enter and

then checking the Puralite periodically. If the Puralite has turned red and the controller alarm has not gone off, access the Diagnostic Loop **unit** display, see below. Check the system run hours, this will give you an accurate DI replacement time. Adjust the DI filter alarm to match the time needed between filter cartridge changes.

NOTE It may be necessary to monitor the Puralite three or four times to establish an accurate changing schedule. Also, DI filter operating time is reduced every time new fluid is added. ▲

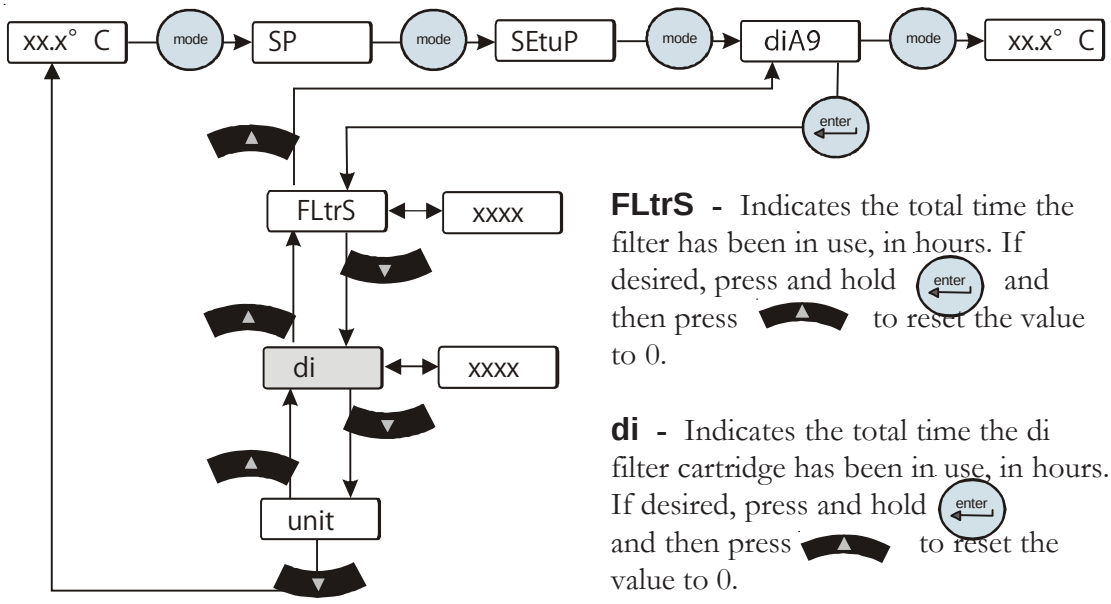


Figure 6-6 Reset

FLtrS - Indicates the total time the filter has been in use, in hours. If desired, press and hold enter and then press ▲ to reset the value to 0.

di - Indicates the total time the di filter cartridge has been in use, in hours. If desired, press and hold enter and then press ▲ to reset the value to 0.

unit - Indicates the unit operating time, in hours. This value can not be reset.

Service Codes

The controller also displays Service Codes. These codes are based on the component run time and are established to avoid unplanned failures. The unit will continue to run. Contact Thermo Fisher Scientific's Customer Support when any of these codes are displayed.

SEr 1

SEr 2

SEr 3

SEr 4

SEr 5

SEr 6

You can press the enter key to clear any service code. Note the service code number because once cleared, the code will not reappear.

Section VII Troubleshooting

Error Codes

The controller can display Error Codes. If the unit is still running press **enter** to see if the code clears, a limit may have been only temporarily exceeded. If the unit shut down the controller will continue to flash the error code. Press **enter** to clear the display and silence any alarm. Once the cause of the shut down is identified and corrected, start the unit. If the cause was not corrected the error code will reappear.

Error Code	Reaction	Cause	Actions
di	Unit will continue to run.	Internal DI cartridge may need to be replaced.	•Check the Puralite sensor on the rear of the unit, if the light is red change the cartridge. See Section VI. •If the Puralite sensor is green, see Section IV to revise DI cartridge run time.
FLtrS	Unit will continue to run.	Air and Fluid filters require preventive maintenance/ replacement.	•Check air and fluid filters. If required, clean/change air and fluid filters, see Section VI. •If your filters do not need cleaning, you may increase the number of hours between preventive care reminders. There are three levels, see Section VI.
HiFLO	Unit reaction depends on HiFLo adjustable setting chosen in the Setup Loop, *Alr setting*. See Section IV.	The process fluid flow rate has exceeded the adjustable setting's value.	•If the unit is still running press enter to see if the code clears, the limit may have been only temporarily exceeded. •Verify your HiFLo setting, see Section IV, and adjust setting if necessary. •Check all application and plumbing shut off valves for correct position. •Adjust flow if unit is equipped with a flow control valve (option), see Section V. •If flow transducer was recently calibrated double check calibration, see Section VIII. •Contact our Sales, Service and Customer Support.

Error Code	Reaction	Cause	Actions
Hi P1	Unit reaction depends on Hi P1 adjustable setting chosen in the Setup Loop, *Alr setting*. See Section IV.	The Pump's discharge pressure exceeded Setup Loop alarm value.	• If the unit is still running press enter to see if the code clears, the limit may have been only temporarily exceeded. •Verify your Hi P1 setting, see Section IV. •Check application valves and ensure that they have not changed or been closed. **NOTE** If routine shut-off of the process flow is required then an external pressure relief valve should be added, see Section V. ▲ • May occur as a result of changing the internal DI cartridge. Disconnecting the cartridge adds an additional 0.5 gpm to the main flow (for PD pumps). See Section V. • Check for debris in the application or external filters. • Double check fluid lines. Excessive bends, long tubing and diameter reductions can affect the pump's discharge pressure. **NOTE** If diameter reductions must be made, they should be made at the inlet and outlet of your application, not at the chiller.▲ •Contact our Sales, Service and Customer Support.
Hi t	Unit reaction depends on Hi t adjustable setting chosen in the Setup Loop, *Alr setting*. See Section IV. **NOTE** If the unit does shut down it can be restarted, but it will shut down again if the process fluid temperature goes above the customer adjustable setting within two minutes.	The Process fluid temperature exceeded Setup Loop alarm value. If operating at high altitude note that heat removal capacity decreases 1.2% per 1,000 feet above sea level. Also, the maximum temperature of the air entering the unit must be reduced by 1°C per 1,000 feet above sea level.	• If the unit is still running press enter to see if the code clears, the limit may have been only temporarily exceeded. •Verify your Hi t setting, see Section IV. •Ensure the unit meets all environmental requirements, see Section III. •Clean air filter. Dirt and debris on filter can prevent the unit from functioning at full capacity, see Section VI. •Ensure that the heat load being applied to the chiller is not too high. Contact Thermo Fisher for assistance on calculating heat loads. •Bring cooler air in from another area or exhaust the hot air into another location using an auxiliary fan. •Ensure unit has adequate ventilation, see Section III. •Verify/adjust controller PID values, see Section VII. •If the internal process temperature sensor (RTD1) was recently calibrated, double check calibration to ensure that it was done properly, see Section VIII. •Contact our Sales, Service and Customer Support.

Error Code	Reaction	Cause	Action
HPC	Unit will shut down.	High refrigeration pressure.	**Air-cooled units** •Clean air filter. Dirt and debris on filter can prevent the filter from functioning at full capacity - see Section VI. •Ensure that the ambient temperature is not exceeding the recommended range, see Section III. •Bring cooler air in from another area or exhaust the hot air into another location using an auxiliary fan. •Ensure unit has adequate ventilation, see Section III. •Contact our Sales, Service and Customer Support. Water-cooled units •Ensure facility water is on and connected •Check facility water flow rate and pressure •Contact our Sales, Service and Customer Support.
Lo P1	Unit reaction depends on Lo P1 adjustable setting chosen in the Setup Loop, *Alr setting*. See Section IV.	Pump's discharge pressure is below Setup Loop alarm value.	•If the unit is still running press enter to see if the code clears, the limit may have been only temporarily exceeded. •Verify your LoP1 setting, see Section IV. •Ensure that chiller reservoir is not empty. •Unit requires >5 PSIG application pressure drop. If a bypass valve has been installed, some restriction may need to be added to the bypass line. •Contact our Sales, Service and Customer Support.

Error Code	Reaction	Cause	Actions
Lo t	Unit reaction depends on Lo t adjustable setting chosen in the Setup Loop, *Alr setting*. See Section IV. **NOTE** If the unit does shut down it can be restarted, but it will shut down again if the process fluid temperature goes below the customer adjustable setting within two minutes. ▲	Process fluid temperature is below Setup Loop alarm value. Unit may not to be able to reach setpoint in low ambient temperatures.	• If the unit is still running press enter to see if the code clears, the limit may have been only temporarily exceeded. •Verify your Lo t setting, see Section IV. •Ensure that the ambient temperature is not exceeding the recommended low-range, see Section III. If your application load is constant and/or the lower temperature can be temporarily tolerated, then continue operation. (The ThermoFlex will control setpoint when sufficient heat is added.) •Verify/adjust controller PID values, see Section VII. •Add insulation to external plumbing lines to reduce the heat-loss to the environment. •Install insulation to external plumbing lines to reduce heat loss. •For water-cooled units check facility water temperature. •Contact our Sales, Service and Customer Support.
LoFLo	Unit reaction depends on LoFLo adjustable setting chosen in the Setup Loop, *Alr setting*. See Section IV.	The process fluid flow rate has gone below the adjustable setting's value.	• If the unit is still running press enter to see if the code clears, the limit may have been only temporarily exceeded. •Verify your LoFLo setting, see Section IV. •Adjust flow if unit is equipped with a flow control valve (option), see Section V. •Check all valves in your application and plumbing lines to ensure that they have not changed or closed. **NOTE** If routine shut-off of the process flow is required then disable the low flow alarm by setting the alarm to 0.5 gpm, see Section IV. ▲ •If flow transducer has recently been calibrated, double check calibration to ensure it was done properly, see Section VIII. •Contact our Sales, Service and Customer Support.

Error	Reaction	Cause	Actions
LLF	Unit will shut down.	Reservoir fluid level too low for normal operation.	•Excessive evaporation. Ensure the unit is operating with the funnel and cap in place. •Check for leaks. •Check auto refill operation, see Section V. •Check the supply pressure on the auto refill supply line. With low pressure the auto refill time span setting may be set too low and the reservoir does not have time to fill. Check rEFiL settings and adjust if necessary, see Section IV. •Contact our Sales, Service and Customer Support.
O FLO	Unit will shut down.	There is an overflow condition in the reservoir.	•Ensure the reservoir was not filled above the MAX LEVEL line. •Check for clogged reservoir filter. •Contact our Sales, Service and Customer. Support. •Check for leaks.
rEFiL	Auto refill will shut off.	The auto refill did not reach the minimum operating level within the time chosen for the customer adjustable *fill* setting, chosen in the Setup Loop, See Section IV.	•Check the supply pressure on the auto refill supply line. With low pressure the auto refill time span setting may be set too low and the reservoir does not have time to fill. Check **rEFiL** settings and adjust if necessary, see Section IV. •Contact our Sales, Service and Customer Support.
		The auto refill successfully filled within the time frame chosen for the customer adjustable *fill* setting, but the unit tries to refill 5 times in 40 hours.	•Check **rEFil** settings and adjust if necessary, see Section IV. •Check for leaks. •Contact our Sales, Service and Customer Support.
Er 4	Unit willl not start.	Normal if new software installed.	•Clear the error code. •If error remains, contact our Sales, Service and Customer Support.
Er 15	Communications error.	No/bad connection.	•Check the serial communication connection. •Contact our Sales, Service and Customer Support.

Error Code	Reaction	Cause	Actions
ER 16	Unit continues to run.	Bad temperature sensor calibration (rtd1).	•Redo rtd1 calibration, see Section VIII. •Contact our Sales, Service and Customer Support.
Er 22	Unit will shut down.	Reservoir fluid exceeded the factory preset value of +43°C. If operating at high altitude note that heat removal capacity decreases 1.2% per 1,000 feet above sea level. Also, the maximum temperature of the air entering the unit must be reduced by 1°C per 1,000 feet above sea level.	•Clean air filter. Dirt and debris on filter can prevent the unit from functioning at full capacity, see Section VI. •Ensure the unit meets all environmental requirements, see Section III. •Ensure that the heat load being applied to the chiller is not too high. Contact Thermo Fisher for assistance on calculating heat loads. •Bring cooler air in from another area or exhaust the hot air into another location using an auxiliary fan. •Ensure unit has adequate ventilation, see Section III. •Verify/adjust controller PID values, see Section VII. •If the internal process temperature sensor (RTD1) was recently calibrated, double check calibration to ensure that it was done properly, see Section VIII. •Contact our Sales, Service and Customer Support.
Er 23	Unit will shut down.	Refrigeration temperature sensor shorted.	•Contact our Sales, Service and Customer Support.
Er 24	Unit will shut down.	Refrigeration temperature sensor open.	•Contact our Sales, Service and Customer Support.
Er 25	Unit will shut down.	Internal temperature sensor shorted.	•Contact our Sales, Service and Customer Support.
Er 26	Unit will shut down.	Internal temperature sensor open.	•Contact our Sales, Service and Customer Support.
Er 32	Unit will shut down.	Refrigeration suction gas temperature exceeded 50°C.	•Contact our Sales, Service and Customer Support.

Error Code	Reaction	Cause	Actions
Er 33	Unit will shut down.	Reservoir fluid below the factory preset value of +3°C.	•Check ambient temperature. Unit may not to be able to reach setpoint at low ambient temperatures. If your load is constant, then turn your unit on. Unit will control setpoint when sufficient heat is added. •Verify/adjust controller PID values, see Section VII. •Add insulation to external plumbing lines to reduce the heat-loss to the environment. •Ensure that the ambient temperature is not exceeding the recommended range, see Section III. •Install insulation if necessary. For water-cooled units check facility water temperature. •Contact our Sales, Service and Customer Support.
Er 35	Unit will shut down.	Process pressure (P1) exceeded factory preset value of 105 psi for greater than 30 seconds. NOTE: A lower Hi P1 dELAY time overrides the 30 seconds and will shut down the unit sooner, see Section IV.	•Check application valves and ensure that they have not changed or been closed. **NOTE:** If routine shut-off of the process flow is required then an external pressure regulator accessory should be added - contact Thermo Fisher. ▲ •May occur as a result of changing the internal DI cartridge. Disconnecting the cartridge adds an additional 0.5 GPM to the main flow (for PD pumps), see Section V. •Check for debris in the application or clogged external filters. •Double check fluid lines. Excessive bends, long tubing and diameter reductions can affect the pump's discharge pressure. **NOTE:** If diameter reductions must be made, they should be made at the inlet and outlet of your application, not the chiller. ▲ •Contact our Sales, Service and Customer Support.
Er 36	Unit will shut down.	Process pressure (P1) below factory preset limit of 3 psi.	•Ensure that the chiller reservoir is not empty. •Unit requires >5 PSIG application pressure drop. If a bypass valve has been installed, some restriction may need to be added to the bypass line. •Contact our Sales, Service and Customer Support.

Error Code	Reaction	Cause	Actions
Er 41	Unit will shut down.	Communication error between display and main control board.	•Cycle circuit protector on rear of unit off and on. •Contact our Sales, Service and Customer Support.
Er 42	Unit will shut down.	Internal communications error.	•Contact our Sales, Service and Customer Support.
Er 48	Unit will shut down.	Unit's EMO button depressed.	•When able, reset EMO.
Er 58	Unit will shut down.	Low flow fault. Flow dropped below 0.1 GPM for more than 15 seconds.	•Adjust flow if unit is equipped with a flow control valve (option), see Section V. •Check all valves in your application and plumbing lines to ensure that they have not changed or closed. **NOTE:** If regular shut-off of the process flow is required then disable the low flow alarm or by setting the alarm to 0.5 GPM, see Section IV. ▲ •If flow transducer has recently been calibrated, double check calibration to ensure it was done properly, see Section VIII. •Contact our Sales, Service and Customer Support.
Er 59	Unit will shut down.	Invalid level fault. Unit sensed both a high level and low level reservoir fluid level.	•Contact our Sales, Service and Customer Support.
Er 62	Unit will shut down.	Shorted remote temperature probe.	•Contact our Sales, Service and Customer Support.
Er 63	Unit will shut down.	Open remote temperature probe.	•Contact our Sales, Service and Customer Support.
Er 64	Unit will continue to run using the last valid setpoint received.	Analog remote setpoint is enabled and the unit receives a voltage or current level that is outside the unit's set point range.	•The error can be cleared only after a valid set point is received, or the remote analog setpoint is turned off.

Checklist

Unit will not start

For first time use, please refer to the quick start instructions included with your unit or the copy in this manual. The manual's copy follows the Table of Contents.

Check the controller for error codes, see Error Codes in this section.

Ensure the circuit protector is in the on (**I**) position.

For Global Voltage units ensure the unit is properly configured, see Appendix B.

Make sure supply voltage is connected and matches the unit's nameplate rating ±10%.

NOTE Once RS232 or RS485 is activated, all keypad operations are disabled except for turning the unit off and changing the serial communication's settings. ▲

Unit shuts down

Ensure  button wasn't accidently pressed.

Ensure the circuit protector is in the on (**I**) position.

Check the controller for error codes, see Error Codes in this section.

Make sure supply voltage is connected and matches the unit's nameplate rating ±10%.

Restart the unit.

Clearing Error Codes

Note the code in case it gets cleared before you are done troubleshooting.

The audible alarm can be silenced by pressing any key.

If the unit shut down the controller will continue to flash the error code. Press **enter** to clear the display and silence any alarm. Refer to Error Codes in this section. Once the cause of the shut down is identified and corrected, start the unit. If the cause was not corrected the error code will reappear.

If the unit is still running press **enter** to see if the code clears, a limit may have been only temporarily exceeded. If the error code does not clear press  until the display flashes between the error code and the temperature and then press **enter.** If the code still does not clear refer to Error Codes in this section.

Unit will not circulate process fluid

Check the reservoir level. Fill, if necessary.

Unit requires >5 PSIG application pressure drop. If a bypass valve has been installed, some restriction may need to be added to the bypass line.

Check the application for restrictions in the cooling lines.

Ensure the reservoir bag filter is not clogged.

The pump motor overloaded. The internal overtemperature/ overcurrent device will shut off the pump causing the flow to stop. This can be caused by low fluid, debris in system, operating unit in a high ambient temperature condition or excessively confined space. Allow time for the motor to cool down.

Make sure supply voltage matches the unit's nameplate rating ±10%.

Inadequate temperature control

Verify the setpoint.

Make sure the condenser/air filter is free of dust and debris.

Ensure your unit's installation complies with the site requirements listed in Section III.

Make sure supply voltage matches the unit's nameplate rating ±10%.

If the temperature continues to rise, make sure your application's heat load does not exceed the rated specifications.

Check for high thermal gradients (i.e., the application load is being turned on and off or rapidly changing).

If operating at high altitude note that heat removal capacity decreases 1.2% per 1,000 feet above sea level. Also, the maximum temperature for the air entering the ThermoFlex must be reduced by 1°C per 1,000 feet above sea level.

Verify/adjust controller PID values, see Section VII.

Ensure the unit was shut down properly, see Section IV. If not the compressor may be damaged.

Unit vibration

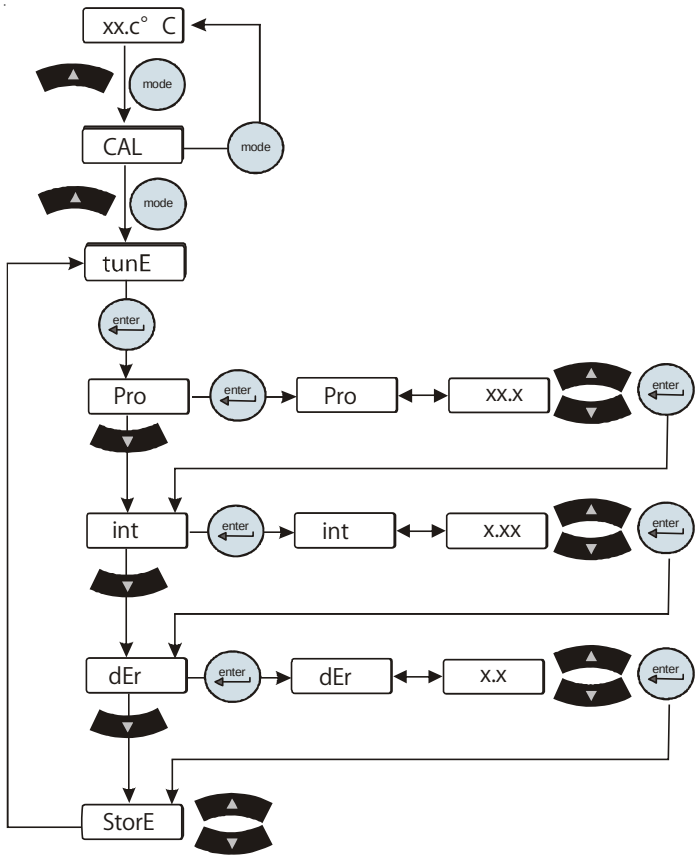
The optional pressure relief valve setting may be the cause. If it is, change the pressure setting ± 5 psi to eliminate the vibration.

Please contact Thermo Fisher Scientific Sales Service and Customer Support if you need any additional information, see inside cover for contact instructions.

Adjusting the Controller PID Values

The controller controls temperature using a Proportional-Integral-Derivative (PID) algorithm. Should your unit experience temperature control issues, adjusting the controller's PID values may correct the condition.

NOTE Thermo Fisher recommends that only a qualified technician adjust the PID values. Incorrect values will hamper unit performance. ▲



• **Pro** is the proportional value
Range: 0.0 to 99.9
Factory Preset: 10.0

• **int** is the integral value
Range: 0.00 to 9.99
Factory Preset: 0.50

• **dEr** is the derivative value
Range: 0.0 to 9.9
Factory Preset: 0.0

Figure 7-1 Adjusting PID Values

Section VII Additional Information

Draining

Before using any fluid or performing maintenance where contact with the fluid is likely refer to the manufacturer's MSDS for handling precautions. ▲

Position a suitable pan beneath the drain port at the rear of the unit. The drain pan must be shallow (under 3½" in height) and have a volume of approximately 3 gallons. Remove ¼" Male NPT pipe plug from drain port. This will drain the return line, reservoir, plate exchanger, and the suction side of the pump.

To drain the discharge side of the pump disconnect the ½" Female NPT outlet connection (the brass fitting) on the rear of the unit.

NOTE Internally the unit does not contain a large quantity of fluid on the discharge side however care should be taken to contain what fluid does drain, a wet-vac can be employed to minimize the potential for spillage. ▲

If the unit is equipped with the anti drainback option, enter the Setup Loop and utilize the **drAin** display to open the valve, see Section IV. Opening the valve allows the fluid to drain out of the unit.

Reinstall ¼" Male NPT pipe plug using a sealant suitable for the wetted materials prior to refilling the unit.

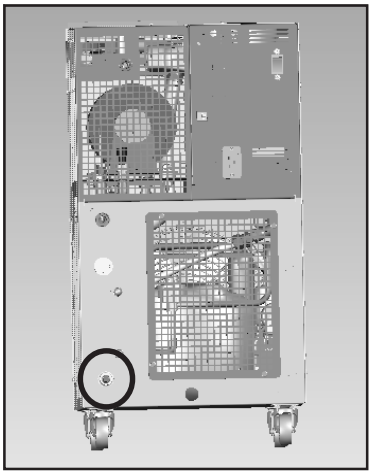


Figure 8-1 1/4" Male NPT Reservoir Drain Plug

Water-Cooled

Draining water-cooled units is accomplished by removing the right side panel. Use a Philips head screwdriver to remove the five screws indicated in the illustration below. Slide the panel back approximately one inch, then lift slightly from the rear to disengage the panel's two tabs from their slots.

Install a $^{7}/_{16}$" ID tube on the drain petcock valve located on the lower end of the exchanger. Open the valve to allow fluid to drain into an external device. When draining is complete close the valve and replace the panel.

A wet-vac is needed on the facility water inlet connection to thoroughly drain any remaining fluid from the lines.

Figure 8-2 Water-Cooled

Intrernal Fluid Temperature Sensor (rdt1) Calibration

The ThermoFlex has been designed to minimize the need for calibration. However, if calibration is desired or recommended by our Sales, Service and Customer Support, please use the following procedure.

This procedure requires that the unit be running, and that a calibrated reference thermometer is available.

NOTE Uninsulated applications may cause the internal temperature and an external reference temperature to be different and fluctuate. If inaccurate calibration is suspected, place the reference thermometer as close to the ThermoFlex process outlet as possible. ▲

NOTE If it is more convenient, the low-end calibration can be performed before doing the high-end. ▲

Do not pick calibration points that are outside the safe operating limits of the fluid in your application. For example with water, 40°C and 5°C would be typical high and low calibration points.

Run the unit to a suitable high-end calibration point. Place a calibrated reference thermometer in the reservoir. Ensure the fluid temperature is stabilized.

To enter the Calibration Loop ensure the controller display is displaying the process fluid temperature, see the diagram on next page. Press and hold the  and then press the 

key. The display will indicate **CAL**.

Press the 

key and the controller will display **rtd1**. Press 

again and the controller will display **r1 H** (high-end calibration). Press 

again and the controller will flash between **r1 H** and the temperature. Use  to adjust the temperature to match the reference thermometer. Press the 

key again to accept the value.

Press the  key until **StorE** is displayed, press  to accept the new value, press  to abort it.

Run the unit to a suitable low-end calibration point. At the **r1 L** (low-end calibration) display repeat the procedure.

Press the  key until **StorE** is displayed, press  to accept the new value, press  key to abort it.

NOTE After pressing the  button at the **StorE** prompt wait several seconds before proceeding to ensure that a bad calibration message (**Er 16**) does not appear. Premature use of the keypad after pressing  may cancel the bad calibration error message. ▲

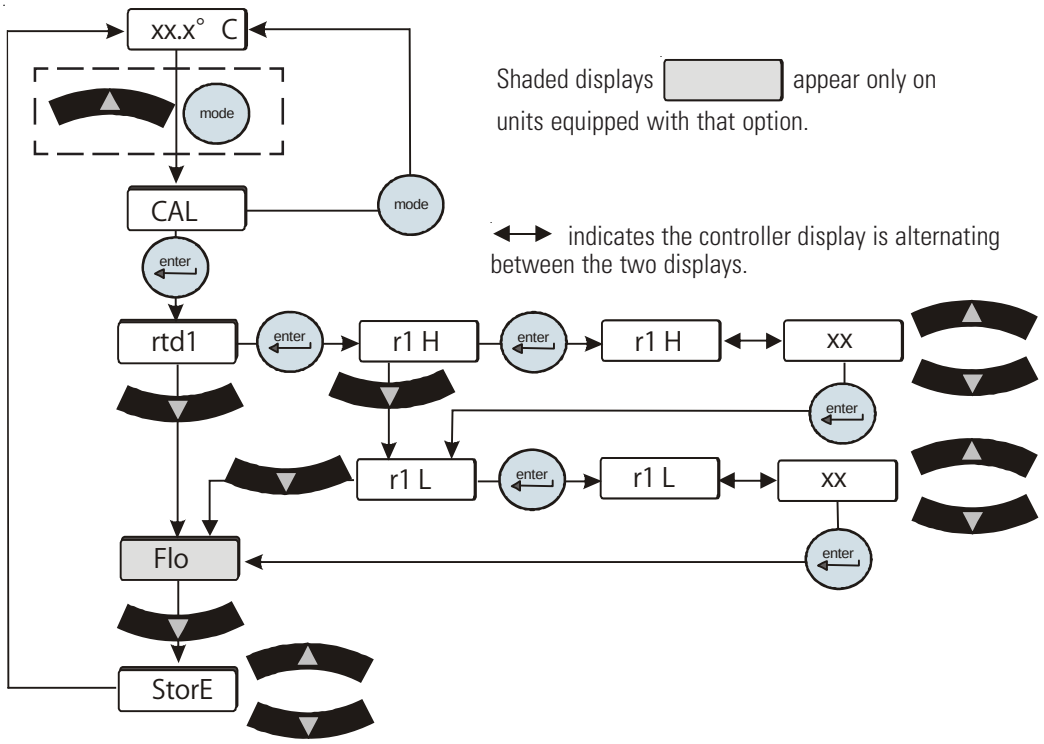


Figure 8-3 Internal Temperature Sensor Calibration

If you have any questions please contact Thermo Fisher Scientific's Sales, Service and Customer Support.

Optional Process Fluid Flow Transducer (FLo) Calibration

The ThermoFlex has been designed to minimize the need for calibration. However, if calibration is desired or recommended by our Sales, Service and Customer Support, please use the following procedure.

This procedure requires the unit to be running, a calibrated reference flowmeter, and an external flow control valve.

Connect a calibrated reference flowmeter to the outlet line. Using an external flow control valve, increase the flow to a suitable high-end calibration point. Ensure the flow is stabilized.

To enter the Calibration Loop ensure the controller display is displaying the process fluid temperature, see the diagram on the next page. Press and hold the  and then press the 

key. The display will indicate **CAL**.

Press the 

key and the controller will display **rtd1**. Press  until the controller displays **FLo**. Press 

and the controller will flash between **HiFLo** and the flow rate. Use  to adjust the rate to match the reference flowmeter.

Decrease the flow to a suitable low-end calibration point.

Press the 

key and the controller will flash between **LoFLo** and the flow rate. Use  to adjust the rate to match the reference flowmeter.

Press the 

key and **StorE** is displayed, press  to accept both values, press  to abort them.

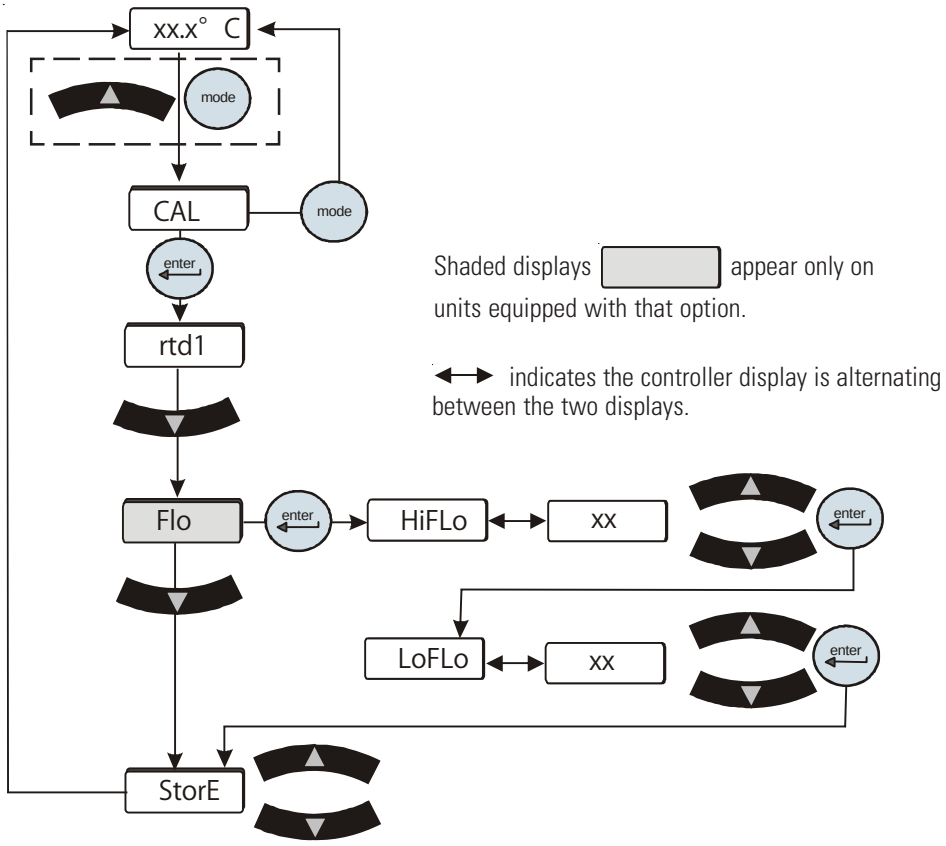


Figure 8-4 Flow Transducer Calibration

If you have any questions please contact Thermo Fisher Scientific's Sales, Service and Customer Support.

Wetted Materials

Pump

300 Series Stainless Steel

Bronze

Carbon Graphite

Ceramic

Fluorocarbon (Viton®)

Polysulfone

Tank

Polyethylene

Brass

Pyrex®

Plumbing

300 Series Stainless Steel

Bronze

Fluorocarbon (Viton®)

Nickel

Polypropylene

EPDM

Brass

Copper

Teflon®

PPS (flow transducer)

Nitrile (Buna-n®)

Funnel

Acetac Copolymer (Celcon®)

Shipment/Storage

If the unit is to be transported and/or stored in near or below freezing temperatures it needs to be drained, see Draining in this Section. The unit can be stored in the temperature range -25°C to 60°C (with packaging), and <80% relative humidity. ▲

Units should not be stored for more than 90 days. ▲

Appendix A Countrty Specific 230 VAC, 50 Hz, 1Ø Requirements

Refer to the nameplate label located on the rear of the unit for specific electrical requirements.

1. Units shipped to the following locations require a **16 Amp service**:

Afghanistan, Albania, Algeria, Andorra, Angola, Argentina, Armenia, Austria, Azerbaijan, Belarus, Belgium, Benin, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Central African Republic, Chad, Chile, Comoros, Congo, Croatia, Czech Republic, Denmark, Djibouti, DR Congo, Ecuador, Egypt, Eritrea, Estonia, Ethiopia, Finland, France, French Guiana, Gabon, Georgia, Germany, Greece, Guinea, Hungary, Iceland, Indonesia, Iran, Iraq, Israel, Italy, Ivory Coast, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lebanon, Liberia, Libya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Mali, Mauritania, Moldova, Monaco, Mongolia, Morocco, Mozambique, Namibia, Nepal, Netherlands, Niger, North Korea, Norway, Paraguay, Peru, Poland, Portugal, Romania, Russia, Rwanda, Saint Vincent and the Grenadines, San Marino, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Slovakia, Slovenia, Somalia, South Africa, South Korea, Spain, Sweden, Switzerland, Syria, Tajikistan, Thailand, Togo, Tunisia, Turkey, Turkmenistan, Ukraine, Uruguay, Uzbekistan, Vanuatu, Vatican City, Vietnam.

2. Units shipped to the following locations require a **15 Amp service**:

Australia, China, Fiji Islands, Nauru, New Zealand, Papua New Guinea, Solomon Island, Tonga, Tuvalu.

3. Units shipped to the following locations require a **13 Amp service**:

Abu Dhabi, Bahrain, Bangladesh, Botswana, Brunei, Cyprus, Dominica, Gambia, Ghana, Gibraltar, Grenada, Hong Kong, India, Ireland, Kenya, Kiribati, Kuwait, Lesotho, Malawi, Malaysia, Maldives, Malta, Mauritius, Myanmar, Nigeria, Oman, Pakistan, Qatar, Saint Lucia, Seychelles, Sierra Leone, Singapore, Sri Lanka, Sudan, Swaziland, Tanzania, Uganda, United Arab Emirates, United Kingdom Yemen, Zambia, Zimbabwe.

Appendix B Global Voltage Configuration Instructions

Units equipped with the Global Voltage option have a voltage configuration panel located behind the refrigeration access panel on the rear of the unit.

- Use a 1/4" socket to remove the four screws securing the access panel to the unit.
- The configuration panel has two 3-position toggle switches, one for voltage and one for frequency. All units are shipped with the toggle switch in the center **SHIP** position. Place each switch to the settings that match the voltage/frequency supplied to the unit.
- Reinstall the refrigeration access panel.

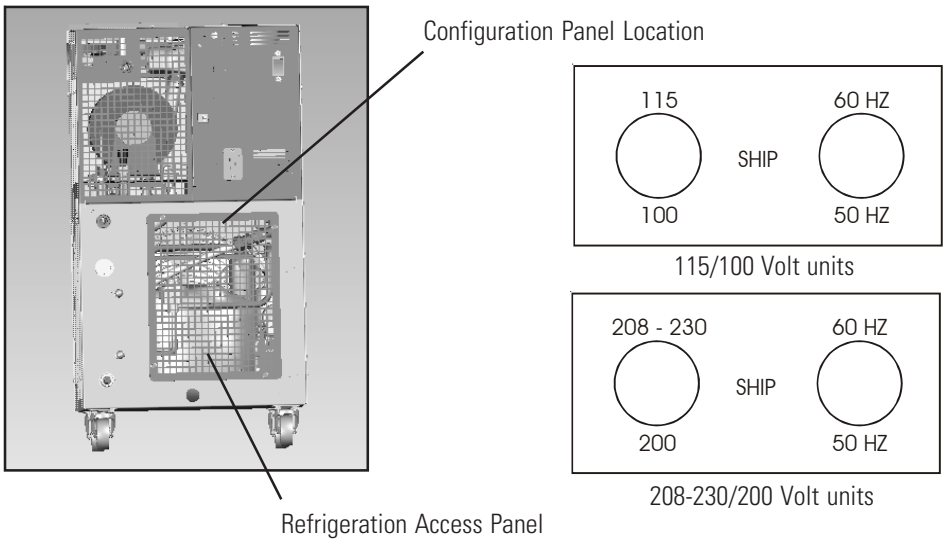


Figure B-1 Global Voltage

Appendix C Analog I/O

Analog I/O Connector Pinout

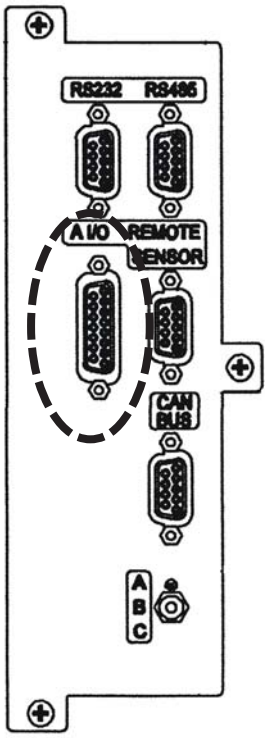
Install your analog input/output device to the 15-pin female connector on the rear of the unit. Analog I/O is activated using the Setup Loop, see next page.

PIN	NAME	NOTES	DEFINITION
1	DIGITAL INPUT COMMON		Common for digital inputs (pins 12, 13 and 14)
2	RESISTIVITY OUT (Only if option chosen)		0-10VDC Analog Voltage Output: Reference to pin 6. This voltage output is proportional to the resistivity of the reservoir fluid: 0.5VDC/M-cm. (Ex: 9.0V = 18 MOhmcm). Maximum output current = 5mA @10VDC.
3	LOW LEVEL (Only if option chosen)	Note 1	Dry Relay Contact: Reference to pin 11. Closes if either level switch is in the "low" position for more than 1 second.
4	CONFIGURABLE RELAY 2	Note 1	Dry Relay Contact: Reference to pin 11. Closes when any configured fault or warning occurs, see Table 2.
5	PUMP ON	Note 1	Dry Relay Contact: Reference to pin 11. Closes when pump is turned on. Opens when pump is turned off.
6	ANALOG GROUND		Common for analog signals (pins 2, 7 and 15)
7	RESERVOIR TEMP OUT **OR** EXTERNAL SENSOR TEMPERATURE IF EXTERNAL SENSOR ENABLED	Note 2	Analog Voltage Output 0-10VDC, 10mV/°C, or 4-20mA: Reference to pin 6. This voltage output is proportional to the reservoir fluid temperature: Default scale= 0–10V (where: 0V = Low Temp Span, 10V = Hi Temp Span) Optional Range = 10mV/ ^{0}C. (Ex: 200mV = 20°C) (Max Load @ 10V = 5mA) or 4-20mA, 4mA = low temp span, 20 mA = high temp span (maximum output current = 5mA @10VDC. Contact us for details.
8	LOW FLOW (Only if option chosen)	Note 1	Dry Relay Contact: Reference to pin 11. Closes when a low flow occurs while the pump is on. Note: To allow the pump to get up to speed at startup, the pump runs for 3 - 5 seconds before the low flow sensor is read.
9	CONFIGURABLE RELAY 1 (Normally Open)	Note 1	Dry Relay Contact: Reference to pin 11. Closes when any of the configured faults occur, see Table 1.
10	CONFIGURABLE RELAY 1 (Normally Closed)	Note 1	Dry Relay Contact: Reference to pin 11. Complement of pin 9 (open when pin 9 is closed).
11	RELAY COMMON		Common for all relay contacts (pins 3, 4, 5, 8, 9, 10).
12	REMOTE START ENABLE	Note 3	Digital Input (Isolated): Reference to pin 1. Connect to pin 1 to allow unit to be remotely turned on/off through pin 14 REMOTE START.

Note 1: All relay contacts (except for Pin 10) are normally OPEN when power is off. Pin 10 contacts are normally CLOSED when power is off. Relay contacts are rated: 24V AC/DC, 2A, <= 0.08 Ohm maximum each or 5A total for all relays combined, 1mA minimum, switching capacity: 48VA/48W (Resistive load only).
Note 2: Jumper Configurable (Default = 10mV/°C)
Note 3: Sink 0.5mA @ 5VDC (Rated for signal level gold contact or TTL device)

PIN	NAME	NOTES	DEFINITION
13	REMOTE SETPOINT ENABLE	Note 3	Digital Input (Isolated): Reference to pin 1. Connect to pin 1 to allow the setpoint to be changed remotely through pin 15 REMOTE SETPOINT.
14	REMOTE START	Note 3	Digital Input (Isolated): Reference to pin 1. Connect to pin 1 to turn unit on. Disconnect to turn unit off. Note: Pins 1 and 12 must be connected to allow operation from this pin.
15	REMOTE SETPOINT	Note 2	Analog Voltage Input 0-10VDC, 10mV/°C, or 4-20mA: Reference to pin 6. Apply a DC voltage to this pin to adjust the unit's setpoint: Default Range = 0 – 10V (where: 0V = Low Temp Span, 10V = Hi Temp Span) (Input Impedance > 600K) Optional Range = 10mV/ ^{0}C. (Ex: 200mV = 20°C) (Max Input Voltage = 10VDC, or 4-20mA, 4mA = low temp span, 20 mA = high temp span. Contact us for details.

Note 1: All relay contacts (except for Pin 10) are normally OPEN when power is off. Pin 10 contacts are normally CLOSED when power is off. Relay contacts are rated: 24V AC/DC, 2A, <= 0.08 Ohm maximum each or 5A total for all relays combined, 1mA minimum, switching capacity: 48VA/48W (Resistive load only).
Note 2: Jumper Configurable (Default = 10mV/°C)
Note 3: Sink 0.5mA @ 5VDC (Rated for signal level gold contact or TTL device)



NOTE When making your connection to the ThermoFlex Analog I/0 connector, in order to comply with the EMC directive:

- Use a shielded I/0 cable
- Connect the remote end of the cable shield to earth ground.
- Connect cable shield to ThermoFlex end connector. ▲

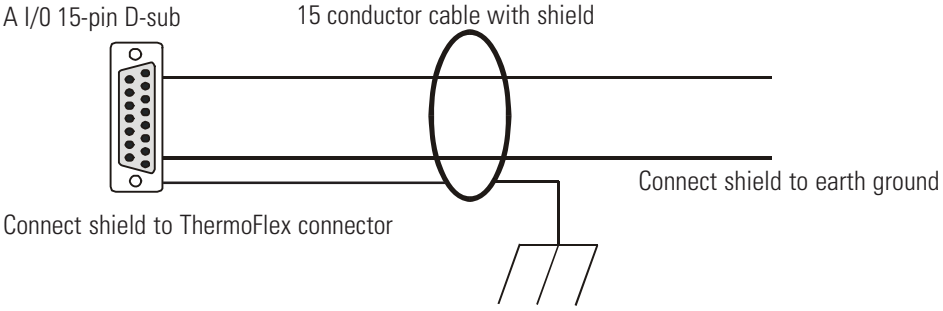
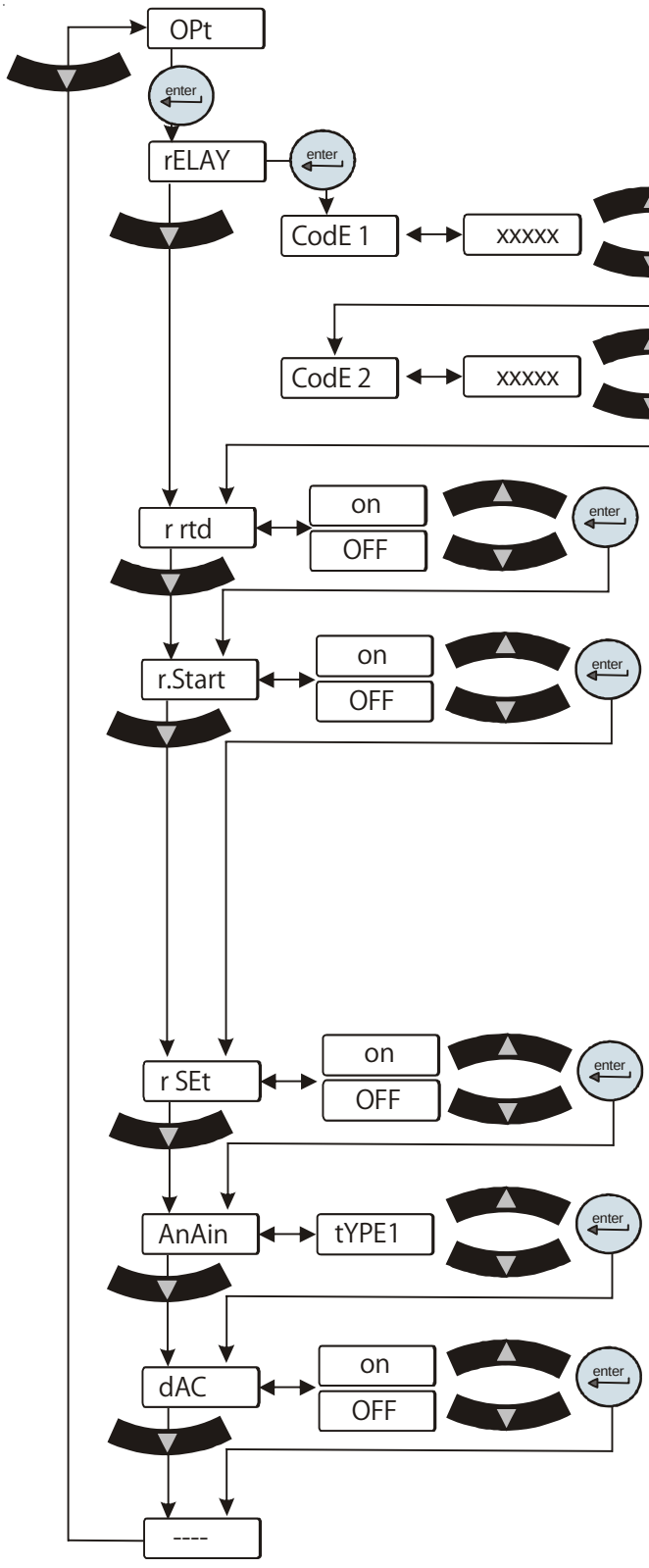


Figure C-1 Analog I/0 Connector



This display depends on you unit configuration, see Section IV.

• **rELAY** is used to configure the code for relays 1 and 2, see Tables 1 and 2 on the next page.

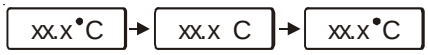
(Example: To have just the tank overflow **or** drip pan error fault activated for either relay you would enter code 6.)

• **r rtd** is used to enable/disable the remote temperature sensor. See Table 3 for pin out information.

NOTE There is no other indication on the unit that the remote sensor is enabled. ▲

• **r.Start** is used to enable/disable the remote start.

NOTE When remote start is enabled a flashing dot will appear on the controller's display as shown below. ▲



NOTE The analog I/O remote start capability has priority over the controller's start/stop, as well as any serial communications start/stop message. ▲

• **r SEt** is used to enable/disable the remote setpoint.

• **AnAin** is used to configure the analog voltage output type.

Type 1: 0 - 10 VDC (Default)

Type 2: 10 mV/°C

Type 3: 4 - 20 mA

• **dAC** is used to enable/disable the digital to analog converter. Once enabled, the desired output type can be selected.

Type 1: 0 - 10 VDC (Default)

Type 2: 10 mV/°C

Type 3: 4 - 20 mA

Table 1	Configurable Relay #1		
Error	Error Number	Factory Default	Code 1
Low Level (option)	31	Enable	1 (Default)
Tank Overflow	44	Disable	2
Drip Pan Full (option)	57	Disable	4
Low Temp	19*	Disable	8
High Temp	21*	Disable	16
Low Flow (option)	27*	Enable	32 (Default)
High Flow (option)	29*	Disable	64
Low Resistivity (option)	28*	Disable	128
High Resistivity (option)	30*	Disable	256
High Pressure	60*	Disable	512
Low Pressure	61*	Disable	1024
Unit Fault	Any Fault	Enable	2048 (Default)
Pump/Unit Shut Off	Status bit(s)	Disable	4096
Refrigeration Shut Off	Status Bit	Disable	8192
Limit Fault (option)	39, 40, 45, 46, 47, 48	Enable	16384 (Default)
Sensor Fault	17, 18, 23, 24, 25, 26+ external sensor opened or shorted	Enable	32768 Default Relay Code 1 = 18465

*Regardless of alarm setting - fault or indicator

Table 2	Configurable Relay #2		
Error	Error Number	Factory Default	Code 2
Low Level (option)	20	Disable	1
Tank Overflow	44	Disable	2
Drip Pan Full (option)	57	Disable	4
Auto Refill Error (option)	43	Disable	8
Low Temp	19*	Enable	16 (Default)
High Temp	21*	Enable	32 (Default)
Low Flow (option)	27*	Disable	64
High Flow (option)	29*	Disable	128
Low Resistivity (option)	28*	Disable	256
High Resistivity (option)	30*	Enable	512(Default)
High Pressure	60*	Disable	1024
Low Pressure	61*	Disable	2048
Indicator (warning)	Any Indicator	Enable	4096
PM Timer (option)	50 - 56	Disable	8192
Comm Error	15, 41, 42	Disable	16384
Sensor Fault	17, 18, 23, 24, 25, 26+ external sensor opened or shorted	Enable	32768 (Default) Default Relay Code 2 = 33328

*Regardless of alarm setting - fault or indicator

Table 3	Remote Sensor Connector Pin Out
Pin	
1	White
2	NA
3	NA
4	White
5	NA
6	NA
7	Red
8	NA
9	Red (4th wire not connected to the control board)

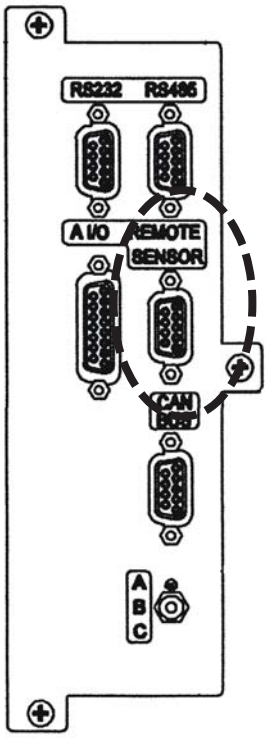


Figure C-2 Remote Sensor Connector

Appendix D NC Serial Communications Protocol

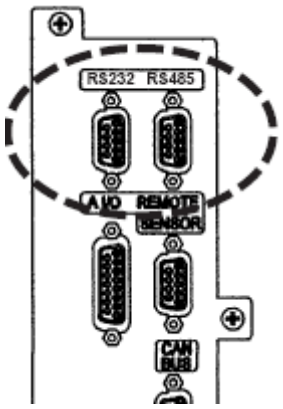
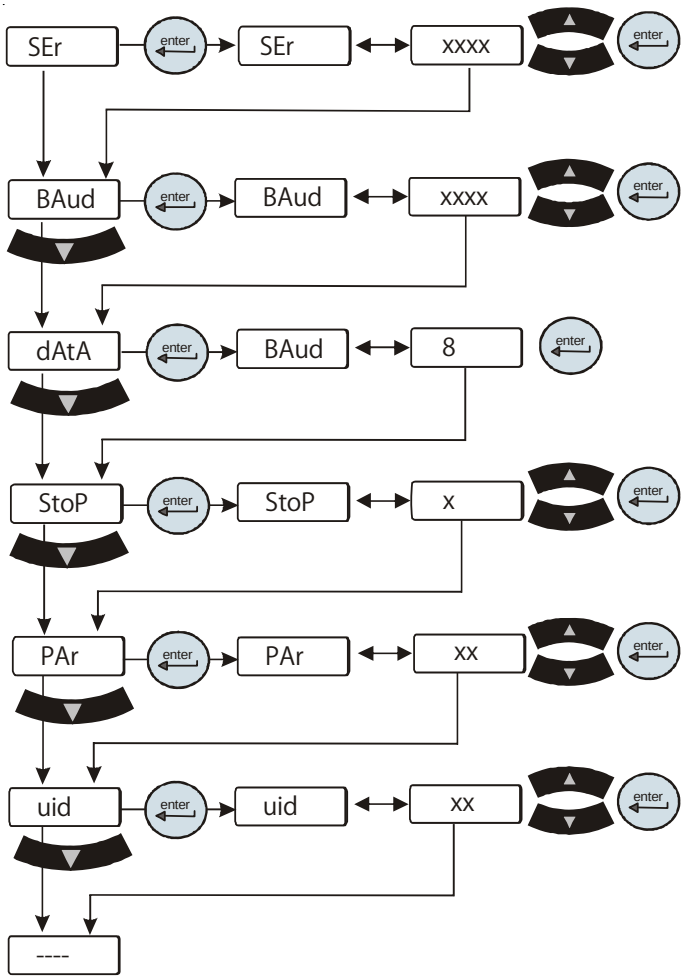


Figure D-1 Connectors

NOTE This appendix assumes you have a basic understanding of communications protocols. ▲

Connect your PC to the applicable connector on the rear of the unit. Use the Setup Loop, see Section IV, to enable serial communications.

NOTE Once RS232 or RS485 is activated, all keypad operations are disabled except for turning the unit off and changing the serial communication's settings. ▲



This display depends on you unit configuration, see Section IV.

• **SEr** is used to enable/disable and to configure serial communications.
Range: oFF, rS232, rS485
Default: oFF

• **BAud** is used to select the speed rate for serial communications.
Range: 9600, 4800, 2400, 1200, 600, or 300 bits
Default: 9600

• **dAtA** is used to display the number of bits per communication.
Range: Fixed at 8

• **StoP** is used to indicate the end of the communication packet.
Range: 2 or 1
Default: 2

• **PAr** is used as a means to check for communication errors.
Range: even, odd, or none
Default: none

• **u id** (unit id) is used in RS485 only. Identifies devices connected the the RS 485 port.
Range: 1 to 99
Default: 1

All data is sent and received in binary form, do not use ASCII. In the following pages the binary data is represented in hexadecimal (hex) format.

The NC Serial Communications Protocol is based on a master-slave model. The master is a host computer, while the slave is the chiller's controller. Only the master can initiate a communications transaction (half-duplex). The slave ends the transaction by responding to the master's query. The protocol uses RS-232/RS-485 serial interface with the default parameters: 9600 baud, 8 data bits, 1 stop bit, and no parity. RS-485 offers a a slave address selection, default parameter: 1.

The unit can be controlled through your computer's serial port by using the unit's standard 9-pin connection.

RS-232 COMM

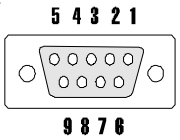
Pin #	Function
1	No connection
2	TX
3	RX
4	No connection
5	GND = Signal ground
6	No connection
7	No connection
8	No connection
9	No connection

TX = Transmitted data from controller
RX = Received data to controller.

RS-485 COMM

Pin #	Function
1	No connection
2	No connection
3	No connection
4	No connection
5	No connection
6	No connection
7	No connection
8	T+
9	T-

Hardware **Mating Connector**
AMP Part# 745492-2 or equivalent



Communication cables are available from Thermo Fisher. Contact us for additional information.

All commands must be entered in the exact format shown in the tables on the following pages. The tables show all commands available, their format and responses. Controller responses are either the requested data or an error message. The controller response *must* be received before the host sends the next command.

The host sends a command embedded in a single communications packet, then waits for the controller's response. If the command is not understood or the checksums do not agree, the controller responds with an error command. Otherwise, the controller responds with the requested data. If the controller fails to respond within 1 second, the host should resend the command.

NOTE All byte values are shown in hex, hex represents the binary values that must be sent to the chiller. **Do not use ASCII.**

The framing of the communications packet in both directions is:

	Checksum region						
Lead char OxCA/OxCC	Addr-MSB	Addr-LSB	Command	n d-bytes	d-byte 1 ...	d-byte n	Checksum

Lead char	**0xCA (RS-232) 0xCC (RS-485)**
	Device address is 1 (RS-232)
Addr-msb	Most significant byte of slave address (RS-232: 0)
Addr-lsb	Least significant byte of slave address (RS-232: 1)
Command	Command byte (see Table of Commands)
n d-bytes	Number of data bytes to follow
d-byte 1	1st data byte (the qualifier byte is considered a data byte)
...	...
d-byte n	nth data byte.
Checksum	Bitwise inversion of the 1 byte sum of bytes beginning with the most significant address byte and ending with the byte preceding the checksum. (To perform a bitwise inversion, "exclusive OR" the one byte sum with FF hex.)

When a command has no value associated with it (e.g. REQ ACK), "n d-bytes" will be set to 0. Values such as temperature and flow are sent as either 2 or 4 byte signed integers, depending on how they are stored in the controller RAM.

When the controller sends a value, a qualifier byte is sent first, followed by a 2 or 4 byte integer (the least significant byte is sent last). The qualifier indicates the precision and units of the value. The host does not send the qualifier byte; it must send the value using the correct precision, units and number of bytes. The host first inquires about a value it wants to change, then uses the number of data bytes and the qualifier byte it receives to generate the proper integer to send.

Analog Values

*Qualifier Byte	
b.7 b.6 b.5 b.4	Precision of measurement
b.3 b.2 b.1 b.0	Unit of measure index

	Unit of Measure
Index	Unit
0	NONE
1	Temperature in °C
2	Temperature in °F
3	Flow liters per minute
4	Flow in gallons per minute
5	Time in seconds
6	Pressure in PSI
7	Pressure in bars
8	Resistivity in MW-cm

E.g., A qualifier byte of 0x12 indicated that the value contains one decimal point and the units are °F , i.e. 98.6°F.

Examples to set setpoint to 25°C:

A. The precision and units are 1°C; a 2 byte integer is used. If you already know this, skip to step 3.

1. Master sends:	CA 00 01 70 00 8E	(Request Setpoint 1)
2. Slave responds:	CA 00 01 70 03 01 00 14 76	Precision =1, units =°C, value=20 (20 x 1°C=20°C)
Response indicates:		
uses a 2 byte integer		(nn=03)
precision and units are 1°C		(d1=01)
3. Master sends:	CA 00 01 F0 02 00 19 F3	(Set Setpoint 1 to 25°C)
4. Slave responds:	CA 00 01 F0 03 01 00 19 F1	Precision =1, units =°C, value=250 (250 x 1°C=25°C)

B. The precision and units are 0.1°C; a 2 byte integer is used. If you already know this, skip to step 3.

1. Master sends:	CA 00 01 70 00 8E	(REQ SETPOINT1)
2. Slave responds:	CA 00 01 70 03 11 00 C8 B2	Precision =0.1, units =°C, value=200 (200 x 0.1°C=20.0°C)
Response indicates:		
uses a 2 byte integer		(nn=03)
precision and units are 0.1°C		(d1=11)
3. Master sends:	CA 00 01 F0 02 00 FA 12	(Set Setpoint 1 to 25.0°C)
4. Slave responds:	CA 00 01 F0 03 11 00 FA 00	Precision =0.1, units =°C, value=250 (250 x 0.1°C=25.0.0°C)

See Additional Command Examples in this Appendix.

Table of Commands

Command	M: Master Sends S: Slave Responds	Notes
Request Status		
REQ ACK	M: lc a1 a2 **00** 00 cs S: lc a1 a2 **00** 02 v1 v2 cs	protocol version v1=0; v2=1
REQ UNIT SW VER	M: lc a1 a2 **02** 00 cs S: lc a1 a2 **02** nn d1 … dn cs	Unit SW version in ASCII
REQ DISPLAY MSG	M: lc a1 a2 **07** 00 cs S: lc a1 a2 **07** nn d1 … dn cs	Display message in ASCII
REQ STATUS	M: lc a1 a2 **09** 00 cs S: lc a1 a2 **09** nn d1 … dn cs	see Request Status Table in this Appendix
ERROR	M: S: lc a1 a2 **0F** 02 en ed cs	Response Only! ed = Error Data en = Error Number 1: Bad Command 2: Bad Data 3: Bad Checksum See Error in this Appendix
Request Measurements		
REQ FLOW1	M: lc a1 a2 **10** 00 cs S: lc a1 a2 **10** 03 d1 d2 d3 cs	Process Fluid Supply Pressure (P1)
REQ TEMP1	M: lc a1 a2 **20** 00 cs S: lc a1 a2 **20** 03 d1 d2 d3 cs	Process Fluid Supply Temperature (RTD1)
REQ TEMP2	M: lc a1 a2 **21** 00 cs S: lc a1 a2 **21** 03 d1 d2 d3 cs	Refrigeration Suction Temperature (RTD2)
REQ TEMP3 S: lc a1 a2 **22** 03 d1 d2 d3 cs	M: lc a1 a2 **22** 00 cs	Refrigeration Ambient Temperature (RTD3)
REQ ANALOG1	M: lc a1 a2 **28** 00 cs S: lc a1 a2 **28** 03 d1 d2 d3 cs	Process Fluid Supply Pressure (P1)
REQ ANALOG2	M: lc a1 a2 **29** 00 cs S: lc a1 a2 **29** 03 d1 d2 d3 cs	Refrigeration Suction Pressure (P2)

Request Low Alarm Values

REQ LO FLOW1	M: lc a1 a2 **30** 00 cs S: lc a1 a2 **30** 03 d1 d2 d3 cs	Process Alarm
REQ LO TEMP1	M: lc a1 a2 **40** 00 cs S: lc a1 a2 **40** 03 d1 d2 d3 cs	Process Alarm
REQ LO ANALOG1	M: lc a1 a2 **48** 00 cs S: lc a1 a2 **48** 03 d1 d2 d3 cs	Pressure Process Supply Alarm

Request High Alarm Values

REQ HI FLOW1	M: lc a1 a2 **50** 00 cs S: lc a1 a2 **50** 03 d1 d2 d3 cs	Process Alarm
REQ HI TEMP1	M: lc a1 a2 **60** 00 cs S: lc a1 a2 **60** 03 d1 d2 d3 cs	Process Alarm
REQ HI ANALOG1	M: lc a1 a2 **68** 00 cs S: lc a1 a2 **68** 03 d1 d2 d3 cs	Pressure Process Supply Alarm

Request PID Settings

REQ SETPT1	M: lc a1 a2 **70** 00 cs S: lc a1 a2 **70** 03 d1 d2 d3 cs	Process Fluid Setpoint
REQ COOL P TERM1	M: lc a1 a2 **74** 00 cs S: lc a1 a2 **74** 03 d1 d2 d3 cs	
REQ COOL I TERM1	M: lc a1 a2 **75** 00 cs S: lc a1 a2 **75** 03 d1 d2 d3 cs	
REQ COOL D TERM1	M: lc a1 a2 **76** 00 cs S: lc a1 a2 **76** 03 d1 d2 d3 cs	

Set Status Settings

SET KEYSTROKE	M: lc a1 a2 **80** 02 d1 d2 cs S: lc a1 a2 **80** 02 d1 d2 cs	See Keystroke in this Appendix
SET ON/OFF ARRAY	M: lc a1 a2 **81** nn d1 … dn cs S: lc a1 a2 **81** nn d1 … dn cs	See Set On/Off Array in this Appendix di: 0 = OFF, 1 = ON, 2 = no change
SET CALIBRATION	M: lc a1 a2 **82** 05 d1 … d5 cs S: lc a1 a2 **82** 07 d1 … d7 cs	See Calibration in this Appendix
SET COPY CALIBRATION S: lc a1 a2 **84** nn d1 d2 d3 cs	M: lc a1 a2 **84** 03 d1 d2 d3 cs	Copy calibration data between unit, backup and reset calibration memory. See Set Copy Calibration in this Appendix.

Set Low Alarm Values

SET LO FLOW1	M: lc a1 a2 **B0** 02 d1 d2 cs S: lc a1 a2 **B0** 03 d1 d2 d3 cs	Process Alarm
SET LO FLOW3	M: lc a1 a2 **B2** 02 d1 d2 cs S: lc a1 a2 **B2** 03 d1 d2 d3 cs	Process Fault
SET LO TEMP1	M: lc a1 a2 **C0** 02 d1 d2 cs S: lc a1 a2 **C0** 03 d1 d2 d3 cs	Process Alarm
SET LO ANALOG1	M: lc a1 a2 **C8** 02 d1 d2 cs S: lc a1 a2 **C8** 03 d1 d2 d3 cs	Pressure Process Supply Alarm

SET High Alarm Values

SET HI FLOW1	M: lc a1 a2 **D0** 02 d1 d2 cs S: lc a1 a2 **D0** 03 d1 d2 d3 cs	Process Alarm
SET HI TEMP1	M: lc a1 a2 **E0** 02 d1 d2 cs S: lc a1 a2 **E0** 03 d1 d2 d3 cs	Process Alarm
SET HI ANALOG1	M: lc a1 a2 **E8** 02 d1 d2 cs S: lc a1 a2 **E8** 03 d1 d2 d3 cs	Pressure Process Supply Alarm
SET SETPT1	M: lc a1 a2 **F0** 02 d1 d2 cs S: lc a1 a2 **F0** 03 d1 d2 d3 cs	Process Fluid Setpoint

SET PID Settings

SET COOL P TERM1	M: lc a1 a2 **F4** 02 d1 d2 cs S: lc a1 a2 **F4** 03 d1 d2 d3 cs	Cool P Term
SET COOL I TERM1	M: lc a1 a2 **F5** 02 d1 d2 cs S: lc a1 a2 **F5** 03 d1 d2 d3 cs	Cool I Term
SET COOL D TERM1	M: lc a1 a2 **F6** 02 d1 d2 cs S: lc a1 a2 **F6** 03 d1 d2 d3 cs	Cool D term

Request Status Table

Basic

nn	4	
	b0	Unit Running
	b1	RTD1 open or shorted
	b2	RTD2 open or shorted
d1	b3	RTD3 open or shorted
	b4	High Temp fixed fault
	b5	Low Temp fixed fault
	b6	High Temp fault or warn
	b7	Low Temp fault or warn
	b0	High Pressure fault or warn
	b1	Low Pressure fault or warn
	b2	Drip Pan fault
d2	b3	High Level fault
	b4	Phase Monitor fault
	b5	Motor Overload fault
	b6	LPC fault
	b7	HPC fault
	b0	External EMO fault
	b1	Local EMO fault
	b2	Low Flow fault
d3	b3	AutoRefill fault
	b4	Sense 5V fault
	b5	Invalid level fault
	b6	Low fixed flow warn
	b7	Low pressure fault (set at factory)
	b0	Low pressure fault (set at factory)
d4	b1	Unit powering up
	b2	Unit powering down

Error

The slave detected an error in the message it received from the master, so it returns this command instead of echoing the command sent by the master. The slave returns the command it received from the master in the *ed* byte, and an error code in the *en* byte.

en	Error
1	Bad command – not recognized by slave
2	Bad data
3	Bad checksum

Some errors may not result in any response. The slave ignores incoming bytes until it sees the valid lead character and its slave address. Then it must receive the correct number of bytes (determined by the length byte) before it can respond. If an incomplete frame is received, the slave will timeout and clear its input buffer without responding.

Set On/Off Array

This command is used to set the state of various features of the unit, such as whether the unit is on or off, and whether the remote probe is enabled or disabled. The number of features and their position in the array is product specific. Sending a 0 in the array turns off or disables the feature while sending a 1 turns on or enables it. Sending a 2 does not change the state of the feature. In all cases, the array is returned showing the state of each feature after the command has been carried out. Sending all 2's effectively turns this command into a request status command.

nn	1
d1	Unit On/Off

Set Keystroke

This command is used to effect a keystroke remotely as if someone pressed the key on the HMI.

Value	
0	Null
1	Enter
2	Up/Yes
3	Down/No
4	Mode
5	On/Off
6	
7	

Set Calibration

This command is used to do a two-point calibration. The command contains the identification of the item to calibrate (RTD1, ANALOG IN 2, etc.), whether it is the high or low point, and the entered calibration value. The controller takes the entered value and the current reading along with the entered value and reading at the other calibration point, and calculates calibration constants. If successful, the pass status byte and the new entered value are returned and the new calculated value matches the new entered value. Otherwise, the fail status byte and the old entered value are returned and the new calculated value matches the old entered value. The return message also includes a qualifier byte that indicates the unit of measure and number of decimal places in the entered value.

Master Sends: lc a1 a2 **82** 05 d1 d2 d3 d4 d5 cs

Slave Returns: lc a1 a2 **82** 07 d1 d2 d3 d4 d5 d6 d7 cs

Master

Byte		Notes
d1	Identifier Byte	Indicates the item to calibrate and whether it is the high or low point.
d2	Entered Value (m.s.b.)	The calculated value should match this after the calibration is complete. This is a 32 bit int which is the value x1000. For example, 20°C is d3 Entered Value represented by 20000.
d4	Entered Value	
d5	Entered Value (l.s.b.)	

Slave

Byte		Notes
d1	Identifier Byte	Indicates the item to calibrate and whether it is the high or low point.
d2	Pass / Fail Byte	0 = Fail; 1 = Pass
d3	Qualifier Byte	Appropriate units; precision=3
d4	Entered Value (m.s.b.)	Returns the most recently accepted calibration point. This is a 32 bit int which is the value x1000. For example, 20°C is represented by 20000.
d5	Entered Value	
d6	Entered Value	
d7	Entered Value (l.s.b.)	

Identifier Byte

Bits	Notes
b.7 (m.s.b)	Low or High 0 = Low; 1 = High
b.6-b.0	7 bit ID:

00h	RTD1	Process
01h	RTD2	Suction
02h	RTD3	Ambient / Water
03h	RTD4	
04h	RTD5	
05h	RTD6	
06h	RTD7	
07h	RTD8	
10h	ANALOG IN 1	
11h	ANALOG IN 2	
12h	ANALOG IN 3	
13h	ANALOG IN 4	
14h	ANALOG IN 5	
15h	ANALOG IN 6	
16h	ANALOG IN 7	
17h	ANALOG IN 8	
18h	RESISTIVITY 1	
19h	RESISTIVITY 2	
20h	FLOW1	
21h	FLOW2	
30h	ANALOG IN 9	
31h	ANALOG IN 10	
32h	ANALOG IN 11	
33h	ANALOG IN 12	
38h	ANALOG OUT 1	
39h	ANALOG OUT 2	

Example: Calibrate the low point of RTD2 at 20°C using RS-232.

Master Sends: CA 00 01 **82** 05 01 00 00 4E 20 08

Slave Returns: CA 00 01 **82** 07 01 01 31 00 00 4E 20 D4

Set Analog Out Cal

This command is used to do a two-point calibration of the analog output.

Master Sends: lc a1 a2 **83** 06 d1 d2 d3 d4 d5 d6 cs

Slave Returns: lc a1 a2 **83** 01 d1 cs

Byte	Master	Slave
d1	ID (1 = ANALOG_OUT1)	Status (1=OK)
d2	MODE see table below	
d3	Entered Value MSB	
d4	Entered Value	
d5	Entered Value	
d6	Entered Value LSB	

MODE	Function	Entered Value
0	Exit	-
1	Set output to high point voltage	-
2	Enter actual high point voltage	Volts x10000
3	Set output to low point voltage	-
4	Enter actual low point voltage	Volts x10000
5	Calibrate	-
6	Set output to mid point voltage	-

Procedure:

– Use mode 1 to set the output to the high point voltage (10V). Use the previous calibration to calculate the DAC value for 10V.

– After the output settles, read it and use mode 2 to send the actual voltage x10000 to the controller.

– Use mode 3 to set the output to the low point voltage (0V). Use the previous calibration to calculate the DAC value for 0V.

– After the output settles, read it and use mode 4 to send the actual voltage x10000 to the controller.

– Use mode 5 to calculate the new calibration constants. The calibration uses the entered voltages and the actual DAC values to calculate the new calibration parameters.

– Use modes 1, 3 and 6 to set the output to 0V, 5V and 10V respectively to check the calibration.

– Exit Analog Output Calibration using mode 0.

Set Copy Calibration

This command is used to copy calibration parameters from one location to another. The source and destination must be different. Use the 7 bit Identifier Byte from the SET CALIBRATION command.

d1	Source	0=Reset; 1=Backup; 2=Unit
d2	Destination	
d3	Calibration ID	See 7 bit Identifier Byte from SET CALIBRATION command.

WARRANTY

Thermo Fisher Scientific warrants for 24 months from date of shipment any Thermo Scientific unit according to the following terms.

Any part of the unit manufactured or supplied by Thermo Fisher Scientific and found in the reasonable judgment of Thermo Fisher to be defective in material or workmanship will be repaired at an authorized Thermo Fisher Repair Depot without charge for parts or labor. The unit, including any defective part must be returned to an authorized Thermo Fisher Repair Depot within the warranty period. The expense of returning the unit to the authorized Thermo Fisher Repair Depot for warranty service will be paid for by the buyer. Our responsibility in respect to warranty claims is limited to performing the required repairs or replacements, and no claim of breach of warranty shall be cause for cancellation or recision of the contract of sales of any unit. With respect to units that qualify for field service repairs, Thermo Fisher Scientific's responsibility is limited to the component parts necessary for the repair and the labor that is required on site to perform the repair. Any travel labor or mileage charges are the financial responsibility of the buyer.

The buyer shall be responsible for any evaluation or warranty service call (including labor charges) if no defects are found with the Thermo Scientific product.

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In addition, this warranty does not extend to repairs made by the use of parts, accessories, or fluids which are either incompatible with the unit or adversely affect its operation, performance, or durability.

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