Norwegian University of Science and Technology
&
CERN

Bachelor Thesis
Electrical Engineering

TELE3001

Project Number E1826

TwinEBIS Control - Development of a LabVIEW Based Control System for Particle Ionisation and Measurement

---

Authors:
Jørgen Steen

E-mail:
jorgstee@stud.ntnu.no

Supervisors:
Dominik Osinski
Odd Øyvind Andreassen

E-mail:
dominik.osinski@ntnu.no
odd.oyvind.andreassen@cern.ch

16th of June, 2019
Faculty of Information Technology and Electrical Engineering
Department of Electronic Systems

NTNU

Preface

Bachelor Thesis

TwinEBIS Control - Development of a LabVIEW Based Control System for Particle Ionisation and Measurement

by Jørgen Steen

The development of the control system and the writing of this thesis was done by me, Jørgen Steen, a student of electrical engineering at NTNU. I am very happy with the result and with all aspects of the control system. It was unfortunate that everything I had done could not be included in this thesis, but due to the scope of the thesis it was necessary to cut away large parts and many specific details. However, even though some things had to be excluded, I still hope this thesis gives a good representation of what the TwinEBIS test bench's control system is capable of. I am proud of what I have managed to create during my year at CERN and the success of the control system.

NTNU

Abstract

Bachelor Thesis

TwinEBIS Control - Development of a LabVIEW Based Control System for Particle Ionisation and Measurement

by Jørgen Steen

————English————

This thesis documents the development of the control system for the TwinEBIS test bench. It is a system that facilities experimentation on the creation of carbon ions for cancer treatment. The thesis comprises of the assessment of requirements, the selection of hardware, the creation of firmware and control software. The requirement documentation was used to select the hardware and develop the software for the control system. The end result is a control system that enables the experiment and is flexible enough to adapt to the changes of the test bench. The flexibility makes it possible to use the system for more experiments than it was originally intended for.

————Norsk————

Dette bacheloroppgaven dokumenterer utvikling av kontrollsystemet til TwinEBIS testbenken. Det er et system som skal hjelpe med eksperimentering med dannelsen av karbonioner for kreft behandling. Bacheloroppgaven består av å vurdere kravene, velge utstyr, lage firmware og kontrollprogramvare. Dokumentasjon med kravene ble brukt til å velge utstyr og utvikle kontrollsystemet. Sluttresultatet er et kontrollsystem som gjør det mulig å utføre eksperimentene og det er fleksibelt not til å tilpasse endringene i testbenken. Fleksibiliteten gjør det mulig å bruke systemet til flere eksperimenter enn det opprinnelig var ment for.

NTNU

Acknowledgements

Bachelor Thesis

TwinEBIS Control - Development of a LabVIEW Based Control System for Particle Ionisation and Measurement

by Jørgen Steen

I want to first of all thank NTNU and Dominik Osinski for making this bachelor's degree a fun and enjoyable experience. Dominik Osiniski for his practical and unique teaching technique, which made me learn a lot more than I normally would. I would also like to thank my supervisor at CERN Odd Øyvind Andreassen for bringing me in and teaching me so much, working with and for him has been a pleasure. I am happy CERN has a program like the technical student program that made my year possible. I am grateful that I shared an office with Ralf Erik Rossel during my time at CERN. He has been an essential part in helping me from the start: if I needed help with anything related to practical information, work in general, or this thesis. He has also become a good friend. I want to thank Dr. Fredrik John Carl Wenander, the physicist in charge of the TwinEBIS test bench. He has been a joy to work with, making the development of the application for his project fun.

I also want to thank my section at CERN, EN-SMM-MTA, and the people it consists of. The working environment has been very good and I enjoy my work tremendously. A special thanks to my colleagues Piotr Jan Koziol and Gary Eric Boorman for helping me proof read my thesis and to Cristovao Andre Dionisio Barreto for being patient and teaching me so much about programming.

List of Abbreviations

CERN	Conseil Européen pour la Recherche Nucléaire
NTNU	Norges Tekniske-Naturvitenskapelige Universitet
PSU	Power Supply Unit
TE	TwinEBIS
GUI	Graphical User Interface
FC	Faraday Cup
ToF	Time of Flight
CMW	Cern Middle Ware
FPGA	Field-Programable Gate Array
GPIB	General Purpose Interface Bus
RT	Real Time
AI	Analog Input
AO	Analog Output
DI	Digital Input
DO	Digital Output
TTL	Transitor Transitor Logic
PXI	PCI eXtentions for Instrumentation
NI	National Instruments
PCI	Periphiral Component Interconnect
cRIO	compact Reconfigurable Input Output
BDV	Beam Diagnostic & Vacuum
BO	Beam Optics
HV	High Voltage
BNC	Bayonet Neill-Concelman & Connector
MCP	Micro Channel Plate
TCP	Transmission Control Protocol
IP	Internet Protocol
RS	Recommended Standard
LabVIEW	Laboratory Virtual Instrument Engineering Workbench

Contents

Chapter 1

Introduction

This thesis describes the design and implementation of the control system for the TwinEBIS test bench based on the specification by the physicist in charge of the project. The introduction will start with a focus on the project itself, before going over to the scope of the thesis. The scope of the project will start at section 1.2 and the scope of the thesis will start at section 1.3.

1.1 The TwinEBIS Test Bench

The focus of the TwinEBIS test bench lies on assessing assessing the feasibility of using an EBIS as the ion source for a next-generation carbon ion radiation therapy facility based on a linear accelerator. Fig.1.1 is a rendition of the TwinEBIS. The name comes from two parts. *EBIS* is an acronym for Electron Beam Ion Source, which means it creates ions with an electron beam. *Twin* comes from the fact it is a copy or a twin of an already existing EBIS called REXEBIS(REX = Radioative beam EXperiment).

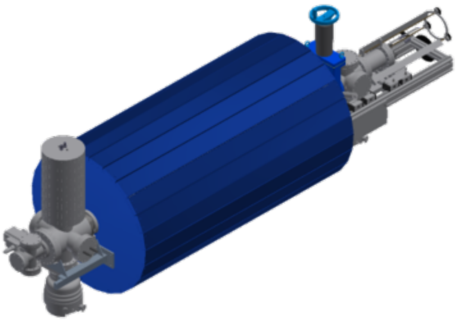


FIGURE 1.1: Graphical Rendition of the TwinEBIS. [9]

Goals of TwinEBIS lab

The goal for the TwinEBIS lab is to provide fundamental research towards a more affordable and technologically advanced carbon cancer treatment. To understand how this is achieved, it is necessary to understand the current state of the treatment. Fig.1.2 illustrates a conceptual design of a future ion beam production facility suitable for installation in a medical treatment center. At the start of the beam line is the EBIS, marked with a yellow circle in the illustration below, and its control system is the main focus of this thesis.

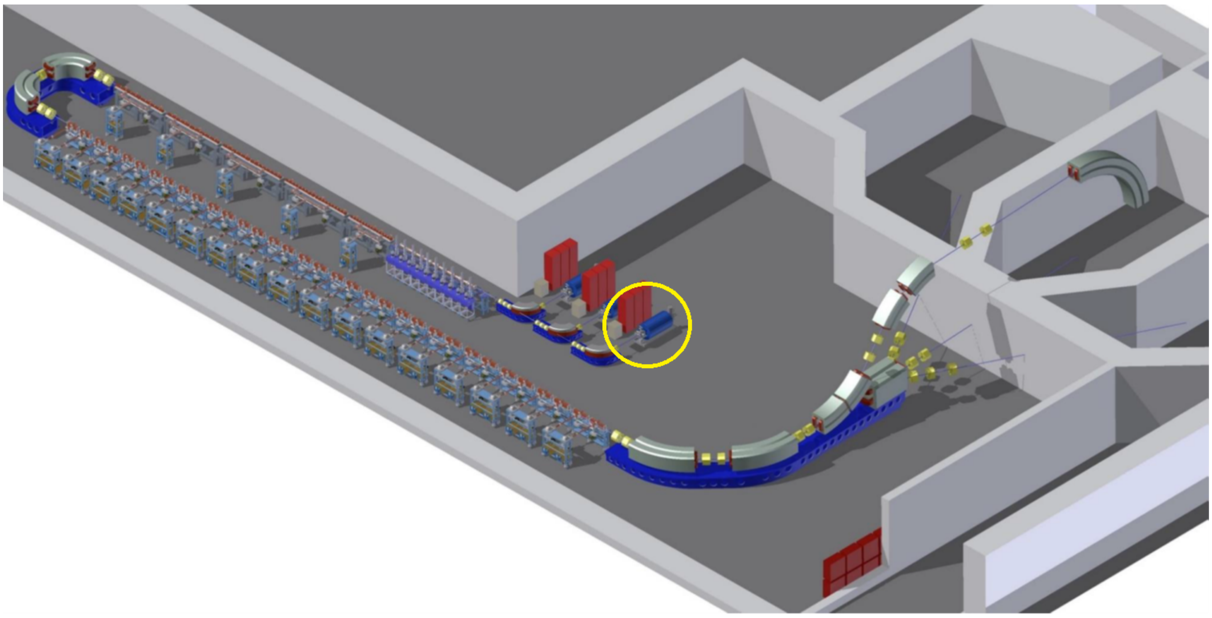


FIGURE 1.2: Illustrates a conceptual design of a future ion beam production facility suitable for installation in a medical treatment center. [2]

1.1.1 Carbon Cancer Treatment

Carbon ion therapy is a form of radiation treatment, where a beam of particles is used to damaged tumor cells. The particles are accelerated to a suitable energy and sent to the patient. In the tissue the particles de-accelerate and release the majority of their energy in a small, selected volume. This has the advantage over many other cancer treatments: there is potentially less collateral damage as the beam mostly damages the targeted tumor and not the tissue around or the whole body[4].

Bragg energy release

Penetration depth of the particles can be controlled by the acceleration energy provided. This can be done with very high precision and this is what makes it possible to directly damage the cancer tumor with minimal damage to the surrounding area.

A graph comparing standard X-ray therapy, proton therapy and carbon therapy is shown in fig.1.3. The protons releases nearly all energy at one depth, while the carbon ions deliver its energy at an even more focused spot. The X-ray deliver most of its energy where it enters and then it slowly decreases as it comes deeper into the tissue. The proton and carbon ions slightly decrease in energy until they travel a critical length, after this they deliver almost all of the remaining energy. This phenomenon is designated as "Bragg Peak"

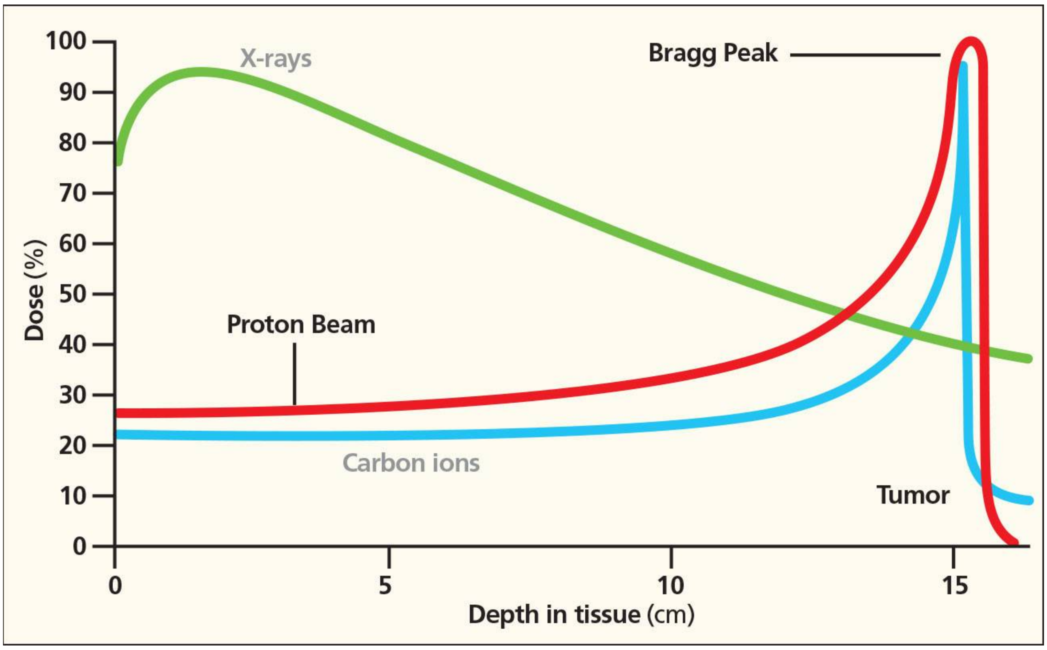


FIGURE 1.3: Bragg Peak, a comparison between normal X-ray treatment and proton and carbon ion treatment. [7]

1.1.2 Problem to solve

Work is underway to reduce the size of the accelerator. Existing particle therapy facilities commonly use protons which offer great advantages over conventional X-ray therapy. However, carbon ions have even more interesting treatment properties, since they can deposit even higher amounts of energy in the cancer cell. Treatment facilities that use carbon nuclei to treat cancer do exist, but since C^{12}, a carbon atom, has about 12 times more mass than a single proton, large circular accelerators have to be used to accelerate them. A circular accelerator keep the beam within the accelerator and accelerates it until the required energy level has been reached. The disadvantages with circular accelerators are that they are so large that it is very hard or impossible to place them into existing medical buildings.

If a hospital wants to have this as a treatment, it would usually have to construct a new building specifically for it. The larger size also means that more materials are needed to build the device in itself, making it even more expensive.

1.1.3 The TwinEBIS lab

An attempt to cut cost is to replace the circular accelerator with a linear accelerator(linac). This requires more accelerating structures since there is only one chance to accelerate the particle to the correct energy-level. However, a linac also offers the advantage of a high repetition rate and an easy adjustability of the beam energy, and hence a tissue penetration depth. This can potentially shorten the treatment time and reduce the complexity of energy adjustment.

While the concept for the accelerator exists, there is currently no ion source that can feed a carbon beam with the appropriate parameters into the linac. An EBIS should theoretically be able to provide the high rate of short carbon ion pulses that are required. Demonstrating this is the current mission of the TwinEBIS lab.

1.1.4 Scope of the Current Test Phase

The goal for the current test phase is to create a reliable way to remove the electrons from the carbon atoms and to provide short ion pulses with a high repetition rate. This means that instead of placing an accelerator at the end of the TwinEBIS, there is a device which measures the charge of the particle. This is done by measuring the time it takes for the particle to travel a set distance with a set energy.

The more ionised particle will travel faster. By determining the intensity of a receiver over time one can see the amount of each group of carbon ions. Fig.1.4 shows a simulation of a result an EBIS can produce. Each of the ions are spread out because of the time it takes to hit the measuring device. This is a simulation and not ideal result, but it represents how the measurement result could look. The goal will be to get as many 6+, C^{12}, ions as possible, meaning all of the electrons have been removed. By doing so the process can be confirmed if it works.

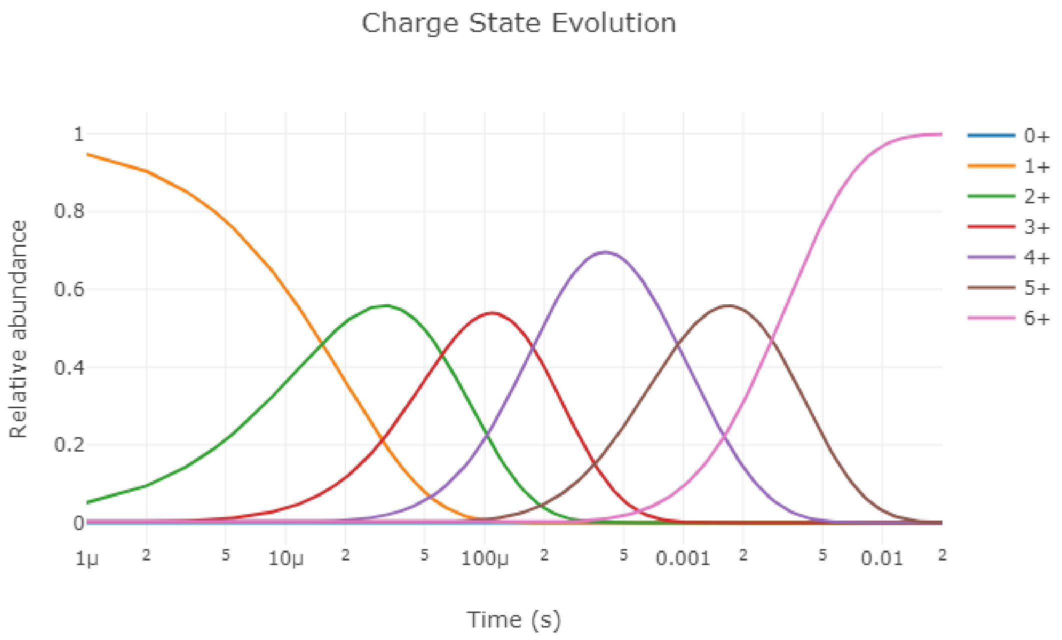


FIGURE 1.4: The abundance of each charge of carbon ion [6]

1.1.5 Operational Cycle

The TwinEBIS test bench operates in cycles. Within this cycle the gas turns into ions and then the gas is measured. This operation cycle is repeated indefinitely until it is interrupted by the operator. In the fig.1.5 this process is visualized. At the end of the cycle the charge of the particle is measured. Alternatively the beam gets interrupted with a Faraday cup. The Faraday cup measures the current of the beam, which is used for diagnostic purposes.

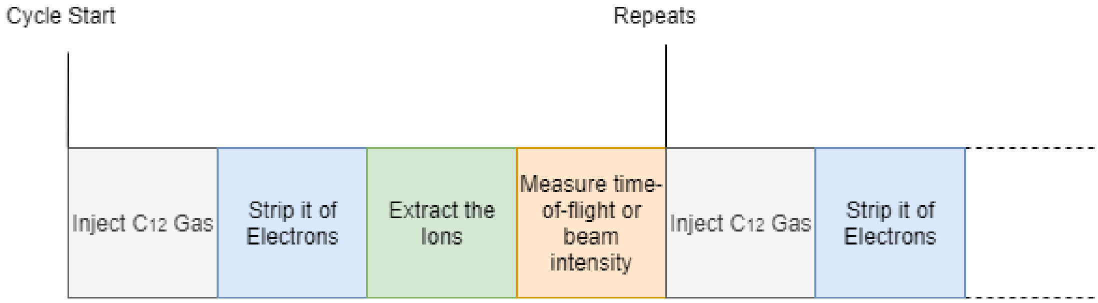


FIGURE 1.5: Cycle content

When the project moves from the test phase to the finished system, accelerating and sending the beam into the patient will also be part of the cycle.

1.2 Control System Scope

The scope of this test phase is to reliably ionise carbon atoms, C^{12}, to a 6+ charge state. The control system will need to facilitate this.

1.2.1 The Control System's Task

To understand the task of the control system for TwinEBIS test bench it is helpful to divide it into smaller parts. Fig.1.6 the project is split into smaller parts.

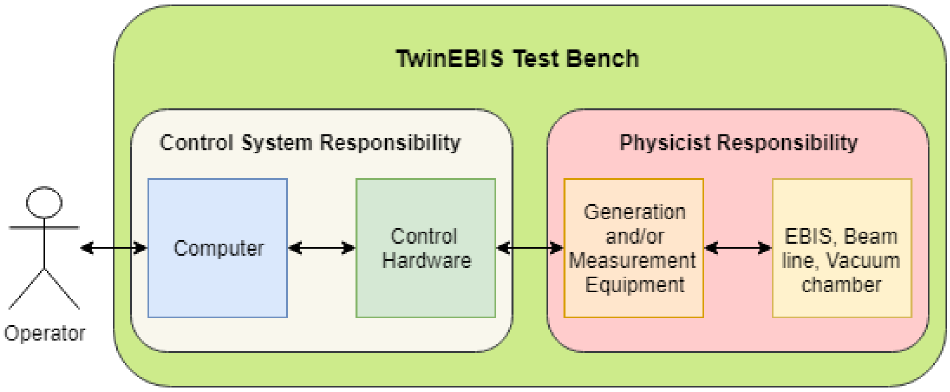


FIGURE 1.6: Responsibility diagram of the TwinEBIS test bench

- **EBIS, beam line and vacuum chamber** consists of the hardware that will directly interact with and surround the beam.
- **Generation and/or measurement equipment** comprises of the physicist's equipment which interacts with EBIS, beam line and vacuum chamber, but is controlled by the control hardware. All of the hardware the physicist sets up has no intelligence, it just does what it is told.
- **Control hardware** is the hardware which controls all of the equipment. The task of the control hardware is to control these devices and add intelligence to the system, like a safety system. The control hardware comprises of the electronics interacting with the low-level equipment. All control algorithms and safety procedures are run here and represent the bulk of the software development described in this thesis.
- **Computer:** is used by the operator to control the test bench. It has to have the ability to send and receive data from the the control hardware. It also has to have an intuitive interface for the operator.

The development work is focused around the control hardware and the interface for the operator. To be able to do this, the hardware has to be selected and bought, documentation for the wiring with and out of the control system needs to be done. A control system and an interface for the operator to interact with the control system is required to be developed.

1.3 Scope of the Thesis

1.3.1 Overview

The focus of the thesis is to analyse the problem, define the requirements, select the hardware and create the software. Fig.1.7 is a conceptual diagram of the TwinEBIS test bench.

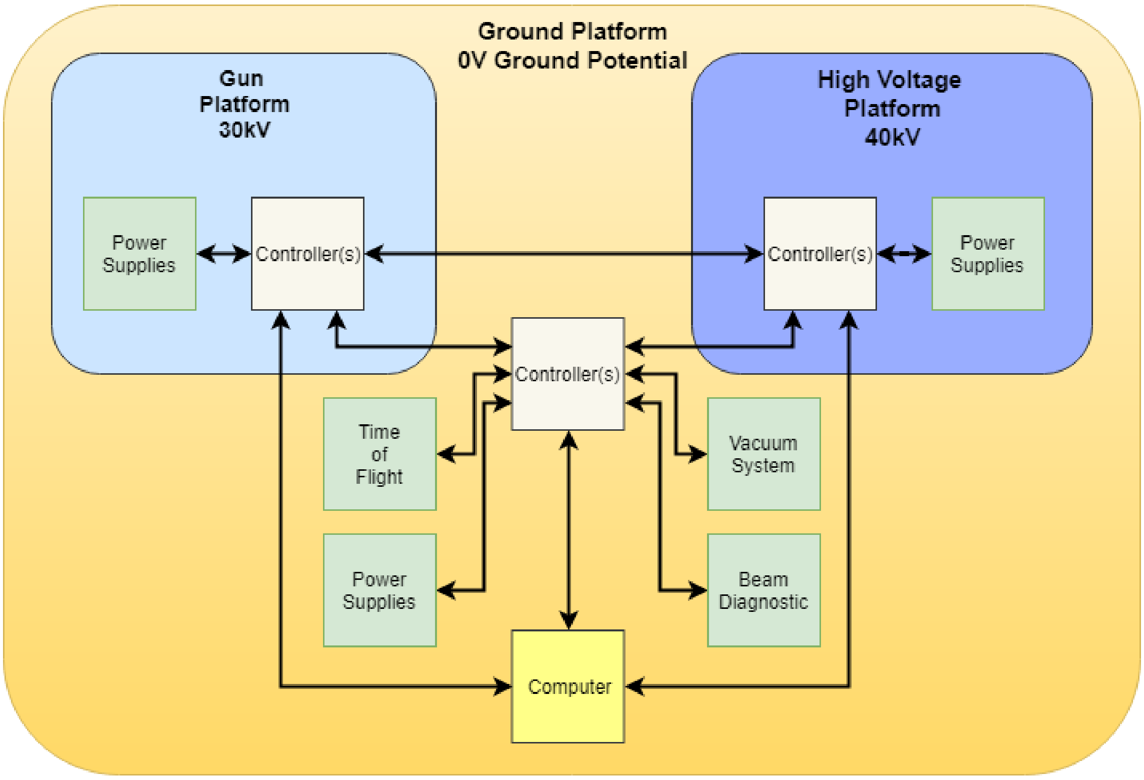


FIGURE 1.7: Simple layout of the platform

The setup is located on three different platforms with a large potential difference between each platform. The voltage is 40kV for the High Voltage Platform, 30kV for the Gun Platform and 0V for the ground platform. There are controllers on every platform and they need to be able to communicate with each other and the computer. The controllers are connected to a variety of devices which are controlled with multiple communication methods.

The task of the control systems will be to control all the devices, enable communication between all the devices and send and get data from the operators computer. This system is required to run reliably for several months.

The key points that will be discussed in the thesis:

- Power Supply Control
  - 58 power supplies connected to the system need to be easily controlled by the user.
  - Similar to an amplifier the Control voltage != Output Voltage. Thus, configurable scaling is needed.
- Vacuum Control
  - The operator needs to be able to create the vacuum needed for the experiments to be successful.
  - Four types of hardware need to be controlled: gauges, gauge relays, pumps and valve. They are controlled using a variety of communication protocols.
- Standardized communication between the devices
  - All the controllers need to be able to communicate with each other and the PC in a unified way on possibly different operating systems.
- Individual self-reliant control system
  - Each controller needs to be self-reliant.
  - The controllers will be dependent on data and signals from each other to perform some of their tasks and this is a necessity.
  - The controllers shall be able to perform their function independently from the operator computer.
- Time critical synchronisation between platforms
  - There are events on the high voltage platform and the ground platform that need to start at the same time.
  - The beam starts at the high voltage platform and the charge is measured on the ground platform. The result of this measurement is time critical.
- High voltage difference between devices
  - Necessity to use a non-metallic communication channels for network and trigger signals to avoid shorting the platforms.
- Wide variety of communication methods with devices
  - The different devices that are a part of the TwinEBIS test bench do not share a common way to be controlled. Analog voltage, parallel communication and serial communication is needed to control all the devices.

- Full stack development
    - The TwinEBIS test bench needs to control the hardware, embedded systems and have a graphical interface on the PC.
    - The developed application application comprise of code that run on FPGA, embedded system and desktop system.

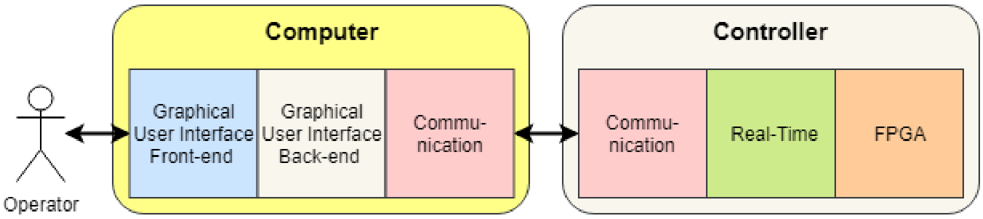


FIGURE 1.8: Included in Full Stack Development

- Interlock system
    - Safety mechanism to stop devices from running during unsafe conditions. The control system will only be in charge of machine safety; human safety interlocks are hardwired.
    - Pumps and valves in the vacuum system
    - Almost all the power supplies are interlocked with a device.
- Identifying the physicist's requirements
    - The physicist's requirements had to be analyzed and refined into a formal specification to allow for proper code development & hardware selection.
- Flexible software appropriate for a test bench
    - As the test bench is not a finished product and it will be more prone to change, it needs to allow for fairly quick and easy adaptions to the experiment setup.
- High speed control
    - Some of the devices the controllers will interface with will operate at speeds of up to 2,000,000 samples per second on multiple channels.
    - The controllers that need to interface with these high-speed devices have to be physically able to do this and have software that will be able to deliver the information fast enough.

1.4 Disposition

- Introduction
  - Introduction to the Project
  - Control System Scope
  - Thesis Scope
- Main Section
  - Requirements
    - Identifying the Requirements
    - Requirement Decisions
  - Solution
    - Discussing the Hardware and Software Selection
    - Development of the Communication Framework
    - Development of the Application for the Controllers
- Result
  - Development
  - Conclusion

1.5 Important Excluded Parts

Creating the control system for the TwinEBIS test bench has taken almost a year and the amount of work gone in to it would not fit into a bachelor thesis. That is why large parts of the work is omitted in this thesis. This section will shortly describe the important parts that were omitted.

1.5.1 Graphical User Interface (GUI)

The GUI was about 20% of the workload for this project. There ware three main challenges with creating the GUI. The visual part the physicist interacts with, the back-end for the visual part that made it do what it should and the sorting of the data received from all the devices and moving it the correct place. There are about 15 GUIs and most of them had different requirements. The number of GUIs was one of the more time consuming parts. The front panel of some of the GUIs will be used in the thesis, but only when it will help to clarify a point. The inner workings of the GUI will not be discussed.

1.5.2 Design and Documentation

To create a control system connected to hardware there needs to be an agreement of the placement of the hardware and the wiring. Creating the documentation for the patch panel, the custom boxes, documentation for configuration and planning the placement of the hardware took time. The process of making it will not be discussed in this thesis even if it was a critical and time-consuming part of creating the control system. All of the documentation is around a hundred pages. This information can be found in E.

Chapter 2

Identifying the Requirements

2.1 Introduction

The specification for a system often describes what the end result should be, but does not give a clear picture of how to get there. The specification for TwinEBIS test bench was no different and had to be re-organised in such a way it was clear what was needed to be done.

This chapter will focus on sorting the documentation presented by the physicist in a way that will highlight requirements for the control system. The documentation will be divided into smaller component, grouped and summarised in a way that is more useful when developing the solutions.

Existing documentation

When worked was started on creating the control system for TwinEBIS test bench there was two pieces of documentation to describe what was needed for the whole system. One document describe all the hardware that would have to be controlled and the other one describing the vacuum system. The vacuum documentation is a layout of the vacuum system and described the various interlocks and the logic it requires. The hardware document described all the devices that will be used in the system, how to interface with them and at which platform they will be located. It also has a short description of the function of the device. There was a lot of information that was not covered in these two documents. To acquire undocumented requirements the physicist was consulted. The vacuum documentation can be found in appendix C and the hardware documentation can be found in appendix D.

2.2 Understanding the Hardware

2.2.1 Power Supply Unit

The PSU description will be a list of all the PSU functions and how to control them. There are two main categories of PSUs: Static and Pulsed. The static PSU should work like a bench top PSU; The operator sets a level which is then kept until the operator decides to change it. The pulsed PSU should work like a waveform generator, but the operator creates their own waveform shape similar to the two waveforms shown in fig.2.1. For the software modelling perspective, many PSUs have common functionality with just a few specific requirements.

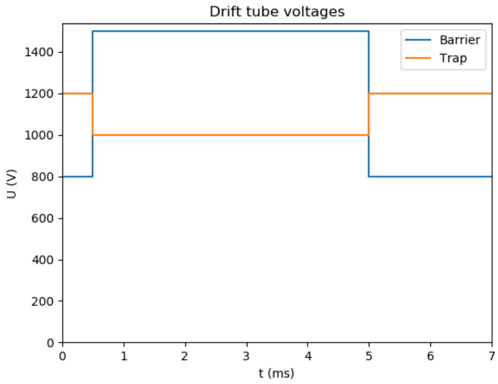


FIGURE 2.1: An example of a pulsed waveform

Specific details about the PSUs can be found in appendix D.

Commonality

The output voltage and current is not the same as the control voltage. The control voltage represents an output current or voltage. Which output level is represented by what control voltage is unique for each type of PSU.

Output	Set	Read
Voltage Level	Voltage Signal	Voltage Signal
Current Level	Voltage Signal	Voltage Signal
On/Off	Short-circuit two wires	-

On/off control

The operator should be able to turn the PSUs on or off, but there is an interlock system that can stop it from going on, even if the operator wants to turn it on.

Exceptions

- The current level cannot be set on all PSUs.
- Not all PSU gives feedback of their output voltage.

Static PSU

The static PSUs are considered slow and do not need to rapidly change between two voltage levels. The documentation specifies 5Hz or faster. The control voltage for all except two PSU is 0-10V. The two exceptions are controlled by 0-5V.

FIGURE 2.2: Static PSU for Deflector

Reversing Polarity Control

Most of the static PSUs only have negative or positive voltage range, but a few are bidirectional PSU, meaning they can go both ways. The control voltage is still 0-10V, but to change polarity the PSU would need to be set to 0V and then a TTL polarity input on the PSU will need to be toggled. When the control voltage is raised again, the voltage will go in the a opposite direction. A low signal TTL signals means positive output voltage and high means a negative one. The PSU can be damaged if the polarity is switched when there voltage is not at 0.

Ramping Voltage

The PSUs connected to the Multi Channel Plate (MCP) and the channeltrons should not change from one voltage to another as fast as they can. They have no internal way to control this, but the controller should facilitate this and the operator should be able to configure the rate of change of voltage per second.

Pulsed PSU

These PSUs pulses a waveform at fast speeds and repeats a sequence for as long as the operator selects it. The pulsed PSUs are controlled in one of two ways.

FIGURE 2.3: Pulsed PSU TREK

Waveform Controlled
The output voltage of a waveform controlled pulsed PSU is a duplicate the shape of the control voltage. The level of the output voltage depends on the relationship between the control voltage and output voltage and they follow the same principles as explained in the common section.

Switching
Each of the switching PSU are controlled by a fast switching TTL signal and two static PSUs. The switching PSU has two inputs one for each PSU. The output of the switching PSU delivers one of the static PSU voltages. Which of them it is depends if the TTL signal is high or low.

2.2.2 Pump

There are two types of pumps: turbo pumps and roughing pumps. The roughing pumps are used to create the initial vacuum and will be close to the outtake of the system. The turbo pumps will be used to create the lower pressure and will be placed between the vacuum chamber and the roughing pump. All of the pumps except one roughing pump is interfaced with RS-485, a serial communication protocol. The single roughing pump that is not controlled with RS-485 is controlled by a 24V signal. So to control it one digital input to read the status and one digital output to set the status. There is an interlock system that can stop all of the pumps from running, if certain criteria are not fulfilled.

FIGURE 2.4: Turbo Pump [1]

2.2.3 Valves

There is only one type of valve in the system. They are open when a 24V signal is sent to them, and 0V will close them. They also indicate their position by outputting a 24V signal if it is open and a 0V signal if it is closed. They draw around 0.25A. They are interlocked with the gauges which can stop them from opening.

2.2.4 Vacuum Gauges

There are three types of gauges: Penning, pirani gauges and backing pirani gauges. Penning gauges measures from 10^{-7} to $10^{-14} bar$ and the pirani measures from $1 - 10^{-7} bar$. Pirani gauges are used at higher pressures and the penning gauge will be used at lower pressure. The penning and pirani gauges give out a value between 0-10V which can be used calculate the pressure. The the backing pirani gauges are interfaced with RS232, a serial communication protocol.

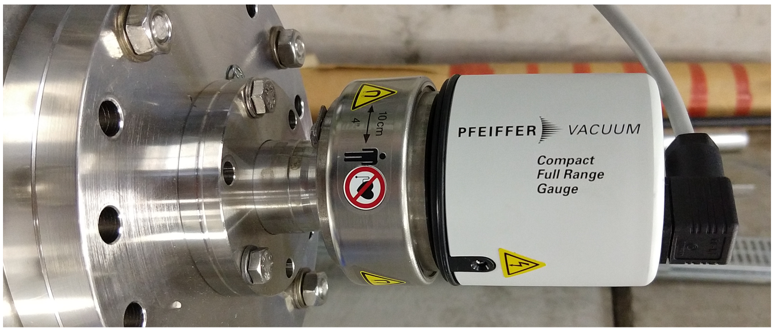


FIGURE 2.5: Gauge

2.2.5 Piston

There are four pistons in the system where three of them will be positioned by a controller. The last one is manually positioned but read by the system. They will have Faraday cups attached to them that will be placed in the beam for measurement. The pistons extend when a 24V signal is sent to them and will retract when 0V is sent. This signal can draw up to 0.25A. The piston controlled by a controller outputs a 24V signal when it is fully extended and nothing when it is in any other position. This means the the measurement will need to be pulled down to ground via a resistor so that it will read 0V when it does not deliver 24V. The manual piston has two output, one that delivers 24V when it is extended and one that that delivers 24V when it is withdrawn.

FIGURE 2.6: Piston connected to a Faraday cup in the vacuum tubing

2.2.6 Gauge Relays & other Interlock-related Devices

The interlock system is meant to keep humans and equipment safe. The gauges relays are manually set to a specific level and will output a 24V signal as long as the pressure is under the set level. If it is above it will output a 0V signal. These gauge relays exist side by side with the normal gauges because they are an important part of the interlock system and should work, even if the control system is down. In this way you can connect hardware switches directly to these relays so the interlock immediately reacts if the pressure is incorrect.

There are other devices that are part of the interlock system. They will also output a 24V or 0V signal. These other devices is made of a variety of measuring devices, one of which is a sensor that check if the door to the high voltage platform is closed.

2.2.7 Faraday Cup

If a Faraday cup is placed into the beam it will generate a current which represent the current level of the beam. The Faraday cups needs to be read in two different ways. If the current is low it will be read by a very accurate pico-amper meter. These can be used manually, but they have a GPIB interface, a parallel communication protocol. This allows them to be set and read from a distance. When the current is higher the faraday cups will be grounded through a resistor and the voltage drop over the resistor will be read by high speed analog inputs. The analog voltage will be +-2V.

2.2.8 Time of Flight

All of the ions will be pushed with the same electric field, but because of their difference in charge they will use different amount of time to travel a set distance. At the end of this distance they will hit the plate that generates current when hit. By measuring the time the ions used to travel the set distance and the current level, one can calculate the abundance of each type of ion. The plate will be grounded through a resistor and the voltage drop will have to be measured by a fast analog input. The voltage will be +-2V.

2.3 High Voltage Considerations

An important aspect to be considered are the three different high voltage levels present in the platforms: Ground Platform, Gun Platform and High Voltage platform.
The difference between the platforms is their references voltage, 0V, ground. On the ground platform, 0V is the same as what we would consider ground in a electrical socket. The High Voltage platform the reference voltage is 40kV higher than what is on ground. The gun platform is -10kV in reference to the High Voltage Platform or +30kV with reference to the ground. It is often referred to as High Voltage -10kV since it is located on the High voltage platform, but isolated from it.

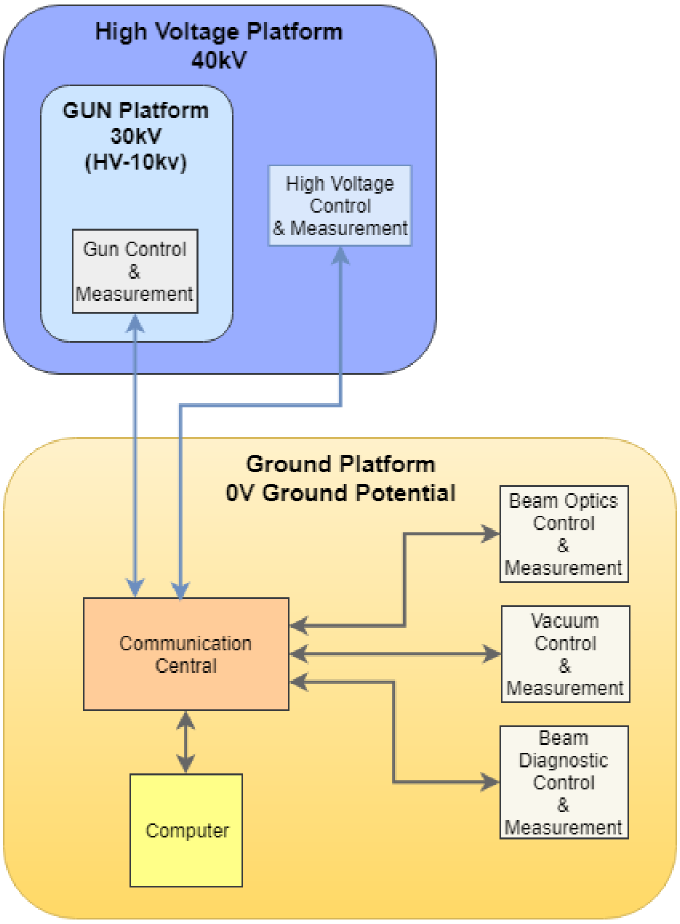


FIGURE 2.7: Topology with regards to tension

2.3.1 What does the High Voltage Difference Mean for the Equipment

The difference in voltage can be measured between platform. A device needing 230V would work just as well on the high voltage platform as it would on ground. Voltage is measured in difference and the platforms have an offset relative to ground.

2.3.2 Challenge with High Voltage Difference

In order to facilitate communication between the devices on different voltage levels, a non-conductive communication connection is required. This means standard probes and cables cannot be used between the platforms which would make it hard to use one controller for multiple platforms.

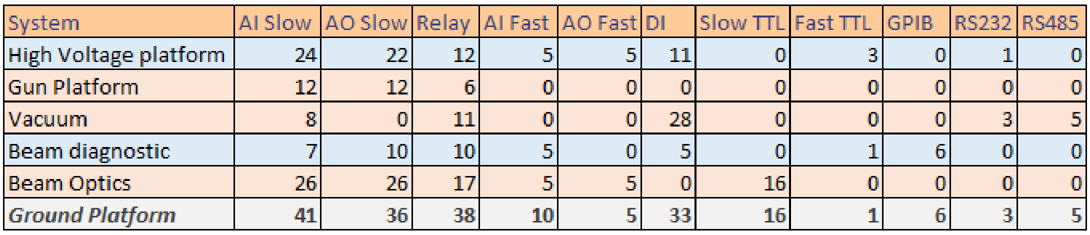
2.4 Identifying the Interfacing Requirements for the Hardware

This section will discuss the interface requirements for the controllers. The focus here will be on what is common and can be grouped together, not on what is unique. This is why most of the details about the hardware will not be discussed here, only its basic interfacing requirements.

2.4.1 I/Os

The hardware documentation, found in appendix D, has multiple pages each one describing different systems; Vacuum, Beam Optics, Beam Diagnostic, Gun and High Voltage. In each of these tabs there is a summery of the types of interfaces needed and the amount needed; AI, AO, RS232, RS485, GPIB, TTL, Relay and DI. These again had two properties, slow or fast. The fast property was only used for the AI, AO and TTL, the rest was counted as slow. Table 2.1 summarises this and has a section for everything that would be located on the ground platform, because one controller could control the different systems located on the same potential if it was practical and cheaper.

TABLE 2.1: Hardware interface Table



System	AI Slow	AO Slow	Relay	AI Fast	AO Fast	DI	Slow TTL	Fast TTL	GPIB	RS232	RS485
High Voltage platform	24	22	12	5	5	11	0	3	0	1	0
Gun Platform	12	12	6	0	0	0	0	0	0	0	0
Vacuum	8	0	11	0	0	28	0	0	0	3	5
Beam diagnostic	7	10	10	5	0	5	0	1	6	0	0
Beam Optics	26	26	17	5	5	0	16	0	0	0	0
Ground Platform	41	36	38	10	5	33	16	1	6	3	5

2.4.2 Specific Requirements

The focus will now shift to the more specifics details and look at what can and cannot be grouped together of the various interfaces. The properties that will be compared is sampling rate, operational range with regards to voltage and resolution in bits.
Using bits to note resolution can be a bit misleading since having the same bit resolution over 0-10V and 0-5V will actually mean that measuring from 0-5V is twice as accurate, if voltage was the only different factor.

The reason for grouping as much as possible together is this would decrease the amount of connections and possibly controllers needed and this could reducing price and the complexity of the system.

Slow Analog Input

The slow AIs will only be used to read gauges and PSU levels. The measurement range requirements for all the gauges go from 0-10V and almost all PSU do so too, with the exception of two which goes from 0-5V.

Something that can measure 0-10V can measure 0-5V, so grouping them together seems very practical. The only thing that could be a stop for this would be if the requirement for the resolution would not be compatible. The resolution requirement for all the PSU is to have 14 bit over 10V which is sufficient for all analog reading and writing. This means that all the slow AI can be seen as the same.

Slow Analog Output

The slow AOs are only used to control PSU. Like the AI they are all required to measure between 0-10V except two which measures from 0-5V. Like the AI they can be grouped together.

Slow TTL

The slow TTL is only used to control the polarity of some of the PSU. It is required to follow the TTL standard, where a low signal is between 0-0.4V and a high Signal is from 2.5V to device supply voltage [10]. All the PSUs that has this function is part of the "Beam Optics" system and can be grouped together.

Fast Analog Input

This will be used to read some of the pulsed PSU, FC reading and MCPs. The five on the HV is used for PSU readings and requires 12bit resolution, -10V to +10V and a sampling rate of 2MHz. On the ground there are two groups of five where the group that reads FCs and MCPs require 10bit resolution, +-2V and a sampling speed of 2MHz on at least two channels at the time. The other group is used to read PSUs and will need 12 bit resolution, -10V to +10V and 100kHz sampling rate.

Fast Analog Output

This will only be used to control the pulsed PSU. There are two groups of fast AO, five on the HV-platform and five on ground. They both require -10V to 10V and 12 bit resolution, but the one on HV-platform requires a minimum sampling rate of 2MHz per channel, and the one on ground requires 100kHz per channel.

Fast TTL

The Fast TTL will be used to control the switching PSU on the HV-Platform and send a trigger signal on ground. They both have to follow the TTL standard and have sample at 2MS/s (mega-samples per second). The three on the HV-platform can be grouped together.

DI

The digital inputs will be reading gauge relays, various interlock signal, position of pistons and valve, and one pump status. They are all 24V and can grouped together as far as the platforms allow.

GPIB

GPIB will be used to communicate with "Keithley 485 picoammeter". They are all part of the beam diagnostics and can be grouped together. With one GPIB port one can control many devices. This means one controller needs to have one GPIB port.

RS232

There is a total of three RS232 and they are a part of the vacuum system. They will be reading gauge levels. RS232 is made for one port per connection, except for some specific circumstances which is not the case here, so there needs to be three RS232 ports.

RS485

There is a total of five devices that has a RS485 interface and they are all pumps that are a part of the vacuum system. RS485 works in parallel so with one port one can control multiple devices. So we need one port to control all the pumps.

Relay

All of the systems have relays. This is because it is used to control pistons, a pump, valves and turn the PSU on and off. Switching the PSU on of require little to no current, but the rest requires at least 0.25A each. They can be grouped together depending on the solution, but before that it is practical keep the separated.

2.4.3 Cross platform Synchronization

The pulsed PSUs and the measurement are all done within a set time frame. This operation is cyclical in natural as it repeats until it is stopped. It will referred to as the cycle. The measurement and the PSUs are spread out on two platforms, the high voltage and ground platform. To keep these processes synchronized there needs to be signal between the platform indicating the start of the cycle. The cycle can not have more than 0.5us jitter. Synchronization between controllers is often done with a trigger, so an additional TTL output and input would be needed.

Chapter 3

Requirements

3.1 Introduction

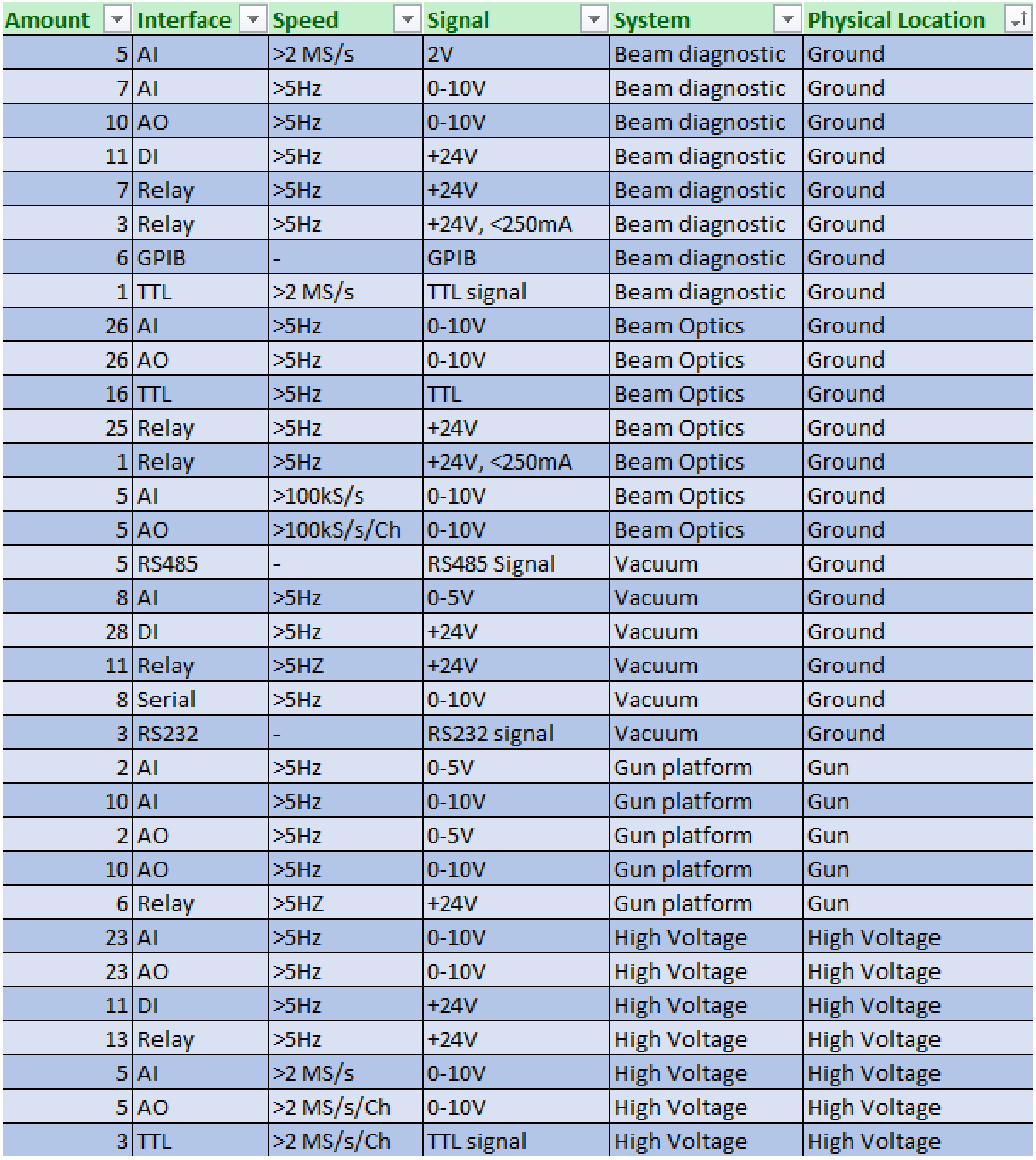
This section will use the results from the previous chapter to create clear requirements for the development of the TwinEBIS test bench control system.

The requirements for TwinEBIS test bench are divided into three parts: hardware, high voltage considerations and software. They are related, therefore some information will be repeated, but the division is created because they can be solved somewhat in isolation. The goal of this modular description is to increase efficiency and reduce errors caused by misunderstandings when developing the control system for the TwinEBIS test bench.

3.2 Hardware Requirements

The information gathered and categorised in the previous chapter was used to create the table shown in fig.3.1. The interfaces which had the same properties and were part of the same system were grouped together. The properties chosen were: Interface, Speed, Signal type(voltage and current requirements), which system it was a part of and the physical location.

TABLE 3.1: Hardware Requirement Table



Amount	Interface	Speed	Signal	System	Physical Location
5	AI	>2 MS/s	2V	Beam diagnostic	Ground
7	AI	>5Hz	0-10V	Beam diagnostic	Ground
10	AO	>5Hz	0-10V	Beam diagnostic	Ground
11	DI	>5Hz	+24V	Beam diagnostic	Ground
7	Relay	>5Hz	+24V	Beam diagnostic	Ground
3	Relay	>5Hz	+24V, <250mA	Beam diagnostic	Ground
6	GPIB	-	GPIB	Beam diagnostic	Ground
1	TTL	>2 MS/s	TTL signal	Beam diagnostic	Ground
26	AI	>5Hz	0-10V	Beam Optics	Ground
26	AO	>5Hz	0-10V	Beam Optics	Ground
16	TTL	>5Hz	TTL	Beam Optics	Ground
25	Relay	>5Hz	+24V	Beam Optics	Ground
1	Relay	>5Hz	+24V, <250mA	Beam Optics	Ground
5	AI	>100kS/s	0-10V	Beam Optics	Ground
5	AO	>100kS/s/Ch	0-10V	Beam Optics	Ground
5	RS485	-	RS485 Signal	Vacuum	Ground
8	AI	>5Hz	0-5V	Vacuum	Ground
28	DI	>5Hz	+24V	Vacuum	Ground
11	Relay	>5HZ	+24V	Vacuum	Ground
8	Serial	>5Hz	0-10V	Vacuum	Ground
3	RS232	-	RS232 signal	Vacuum	Ground
2	AI	>5Hz	0-5V	Gun platform	Gun
10	AI	>5Hz	0-10V	Gun platform	Gun
2	AO	>5Hz	0-5V	Gun platform	Gun
10	AO	>5Hz	0-10V	Gun platform	Gun
6	Relay	>5HZ	+24V	Gun platform	Gun
23	AI	>5Hz	0-10V	High Voltage	High Voltage
23	AO	>5Hz	0-10V	High Voltage	High Voltage
11	DI	>5Hz	+24V	High Voltage	High Voltage
13	Relay	>5Hz	+24V	High Voltage	High Voltage
5	AI	>2 MS/s	0-10V	High Voltage	High Voltage
5	AO	>2 MS/s/Ch	0-10V	High Voltage	High Voltage
3	TTL	>2 MS/s/Ch	TTL signal	High Voltage	High Voltage

The data in table above clearly indicates the minimum requirements for the interface of the controllers. This is a test bench i.e. a prototype, which means it will probably expand and the amount of connections for each interface group is expected to increase in further adaptations.

3.3 Special Requirements for Tension difference

The difference in tension makes it impossible to use electrically conducting wires between the platforms. Most devices communicate using electrical signals by default and do not have any extra interface to communicate between tension. This will most likely be true for any equipment selected for this project too. For this reason the communication between platforms needs to make use of a non-conductive communication medium and thus must employ corresponding media converter hardware. The synchronization between the time critical events that happens between the high Voltage platform and the ground platform will also have to be converted to a non-conducting medium and back again.

3.4 Software Requirements

The software requirement will draw on the devices mentioned in the identifying requirements chapter to find out how and what the software must do. This section will clarify the required behavior of the software.

3.4.1 Cycle of the program

The program operates in cycles which runs repeatedly for as long the it turned on. When it is turned off, it should not run at all. It is critical that the timing of the cycle is accurate, both when it starts and how long it lasts. The operator must have to set the length of this cycle and all the processes dependent upon the cycle time will need to receive the newest value. The cycle time can be between five seconds and two milliseconds. All operation that runs in the cycle will need to have this bandwidth. The operator also has to be able to start and stop the cycle.

3.4.2 Power Supply Unit Control

In the chapter on identifying the requirements there is an overview over all the functionality for the PSU. The focus here will be on what is required from the software for each of the functions and not on the individual requirements for a PSU.

Setting the Voltage Level

The controller of the PSU delivers a low voltage which represents a higher voltage. The software needs to scale the set voltage to the control voltage so that the operator only sees and interacts with the output voltage of the PSU. The sensitivity between the control voltage and the output voltage is unique for each PSU. The function for conversion is linear. This relationship will need to be configurable for each individual PSU.

Reading the Voltage Level

Like the setting of a voltage, the reading of the voltage is scaled down. To know which voltage this represents one can use the inverse function to calculate the setting of the voltage. This means the same PSU configuration for setting the voltage can also be used for reading it.

Setting the Current Level

The controller of the PSU delivers a voltage which represents a current. The software needs to scale the set current to the control voltage so that the operator only sees and interacts with the output current of the PSU. The sensitivity between the control voltage and the output current is unique for each PSU. The function for conversion is linear. This relationship will need to be configurable for each individual PSU that has this functionality.

Reading the Current Level

The output level of the current for the PSU is indicated by a voltage. The function to scale this into current is the inverse of the function for setting the current, which means the same PSU configuration for setting the current can also be used for reading it.

Turning on and off

All of the PSUs have two sense wires that control if they are on or off. This requires software that tells the hardware to open and short them on command. There will also be an interlock mechanism that will control if the user is allowed to turn the PSU on. This will be explained in more detail in another section.

Polarity switching

All the PSUs in the beam optics system that are bi-polar needs a TTL signal to change polarity. The software need to control this automatically. When a change in polarity is initiated the software should first set the PSU to 0V and when 0V is confirmed, it should then switch the TTL signal and set the voltage to the requested level.

Ramping Voltage

A few of the PSUs should not be automatically set to the selected voltage, but they should slowly ramp up to it. The operator will need to configure this speed and will do so in V/s, but the value to the PSU should be updated 10 times a second so the increment needs per update needs to be 10 times lower than the set value. This PSU property will need to be configured individually.

3.4.3 Setting Configuration

The operator needs to be able to set the relationship between the control voltage and the actual voltage and current and the max current and voltage. The operator also needs to be able to set the ramping voltage for the static PSU. The function for converting control voltage to current or output voltage is linear. The information the operator needs to supply for software to calculate this is:

- Minimum control voltage for output voltage [V]
- Minimum PSU voltage [V]
- Maximum control voltage for output voltage [V]
- Maximum PSU voltage [V]
- Maximum allowed voltage [V]
- Ramping voltage [V/s]
- Minimum control voltage for output current [V]
- Minimum PSU current [A]
- Maximum control voltage for output current [V]
- Maximum PSU current [A]
- Maximum allowed current [A]

These values needs to be able to saved so the operator only has to edit this whenever there is a change in power supply or max allowed values. The operator also has to have the ability to propagate the change to all the controllers.

PSU handling procedure

- **Interlock and PSU:** Most PSUs are interlocked, and and will turn off if the interlock is broken.
- **Interlock Override:** Each PSU should have a override interlock functionality so the operator can bypass the interlock for a specific PSU.
- **Turning Off a PSU:** The PSU voltage and current control should work separately from the On/Off signal. When the PSU is turned off, the control voltages should remain on the PSU.
- **Max Volt and Current:** The maximum voltage and current that PSU will be allowed to be delivered needs to be configurable. As the PSUs might be able to deliver higher voltages and currents than the system can handle.
- **Negative Voltage settings:** For the PSU that can deliver negative voltages there will not need to be any extra setting. It will use the mirror setting. This is applicable to the max voltage and the voltage scaling. Example: Setting max 500V means also that -500V is max.

3.4.4 The static PSUs

The important quality of the static PSUs are that they will stay on one level until the operator chooses to change it. The operator will change values at a maximum speed of 2Hz so the system needs to be able to response at least at this speed. With a few exception all the slow PSU needs to have these functions in software.

- Voltage and current level will need to be controllable.
- Read current and voltage level
- Turn on/off
- Setting configuration

3.4.5 Pulsed PSUs

The Pulsed PSUs output a waveform instead of a static PSU level. The operator will create a waveform and it will be repeated until it is changed or stopped. All the pulsed PSUs are used to control the particle beam. There are three groups of pulsed PSUs: Deflectors, TREK and Behlke.

Deflector

These are controlled with a waveform with 100.000 or more samples per second. The software needs to create a waveform with the correct amount of samples according to the what the output frequency of the controller.

Operation:
The created waveform will consist of three parts or stages with different time span and voltage level. These stages are: delay, inject and extract. The delay is the time between the the cycle start and the injection of the particle. The inject stage is were the particles gets injected into the TwinEBIS and the extract phase is were the ions are extracted from the TwinEBIS.

Operator Options:
For each PSU the operator should be able to set these times, voltages and an on/off switch. Time will be in us and voltage in volts.

- T_{delay}: Time to wait before it begins
- $V_{injection}$: Injection Voltage.
- $T_{injection}$: Injection Time.
- $V_{extraction}$: Extraction Voltage.

The V_{delay} and $T_{extraction}$ is not possible to set for the operator because they are derived from the other values.

$$T_{extraction} = T_{cycle} - T_{delay} - T_{injection} \tag{3.1}$$

$$V_{delay} = V_{extraction} \tag{3.2}$$

Configuration:
The configuration is identical as described, except that you cannot set the current level on these PSUs.

TREK PSU

The TREK PSUs and the PSUs for the deflector are very similar in how they are handled, the difference is that the TREK will at least have 2.000.000 samples per second and it will have five stages. The TREK PSUs are high voltage high speed PSUs that will set the voltage on the tubes going inn and out of the TwinEBIS. There are a total of four drift tubes and there will be four TREK PSUs. Each one will be controlled in an identical matter.

Operation:
The TREK PSU will have five stages: delay, injection, breed, extraction and clean. The delay, injection and extraction stage is the same as explained above. The breed stage is when the electrons a being removed from the particles. The clean stage is after the ions have been extracted and any stray particles is cleaned away from the inside of the TwinEBIS.

Operator Options:
For each PSU the operator should be able to set these times, values and an on/off switch. Time will be in us and voltage in volts.

- T_{delay}: Time to wait before it begins
- $V_{injection}$: Injection Voltage.
- $T_{injection}$: Injection Time.
- V_{breed}: Breed Voltage.
- T_{breed}: Breed Time.
- $V_{extraction}$: Extraction Voltage.
- $T_{extraction}$: Extraction Time.
- V_{clean}: Cleaning voltage.

The V_{delay} and T_{clean} is not possible to set for the operator because they are derived from the other values.

$$T_{clean} = T_{cycle} - T_{delay} - T_{injection} - T_{breed} - T_{extraction} \tag{3.3}$$

$$V_{delay} = V_{clean} \tag{3.4}$$

Configuration:
The configuration is identical as described, except that you cannot set the current level on these PSUs.

Behlke Supplies

The Behlke PSUs will control the the same four drift tubes as the TREK PSUs but not at the same time. When the Behlke PSUs are being used the two outer drift tubes will be connected together and controlled by the same PSU. This means there will be three Behlke PSUs and each one will be controlled in an identical matter. The behlke PSUs will not be supplied a waveform like the other PSUs because it is a switching PSU described identifying requirements section. This means there will be a total of six static PSU supplying three Behlke PSU with their voltage level and a TTL signal that chooses which of them that are used. The Behlke has a faster switch rate between the levels and is therefor preferred in certain circumstances.

Operation:
Like the deflector the behlke PSU have three stages: delay, injection and extraction. For the operator the behlke control should be identical to the deflector control, the difference lies in what happens after. The voltage levels will need to be sent to the static PSUs connect to the Behlke and the time will need to be sent to the controller with the fast TTL so it can be high and low for the correct amount of time. These settings will create a square waveform which will be repeated as long as the cycle is running.

Operator Options:
For each PSU the operator should be able to set these times, voltages and an on/off switch. Time will be in us and voltage in volts.

- T_{delay}: Time to wait before it begins
- $V_{injection}$: Injection Voltage.
- $T_{injection}$: Injection Time.
- $V_{extraction}$: Extraction Voltage.

The V_{delay} and $T_{extraction}$ is not possible to set for the operator because they are derived from the other values.

$$T_{extraction} = T_{cycle} - T_{delay} - T_{injection} \tag{3.5}$$

$$V_{delay} = V_{extraction} \tag{3.6}$$

Configuration:

The configuration of these supplies will be identical as described, except the current control should always be set to max current.

3.4.6 Functional Description of the Interlock systems for the PSU

In the TwinEBIS test bench, from the software's perspective, there are are two main categories of interlocks; The interlocks that are used to control the PSUs, and the one that are only indicated in software. This section will focus on interlocks that are used by the system to control the PSUs.

The interlocks function is to notify the control system when something is wrong so it can turn off PSUs to prevent damage to equipment. There are a total of 17 interlock signal on the TwinEBIS test bench. There must be an indicator for each of them, but only 10 of them will be used to control functions inside the software.

Interlocks signals in the TwinEBIS test bench

All the interlock signals originate either on the the ground platform or the high voltage platform. The table below list all the interlocks that will be read by the TwinEBIS test bench control system. Under topic "use" there are two letters used to tell which ones that will be indicated and control the system. Indication is marked with I and control marked with C.

Table of the Interlocks that will be used in software P.G.R = Penning Gauge Relay

Interlock Name	**Location**	**System**	**Use**
Gun P.G.R	HV Platform	High Voltage	I & C
Collector P.G.R	HV Platform	High Voltage	I & C
Cathode heating Interlock	HV Platform	High Voltage	I & C
Separator Magnet Temperature	Ground Platform	Vacuum	I & C
Separator Magnet Water Flow	Ground Platform	Vacuum	I & C
EBIS Branch P.G.R	Ground Platform	Vacuum	I & C
RFQ P.G.R	Ground Platform	Vacuum	I & C
TOF P.G.R	Ground Platform	Vacuum	I & C
Ion Source P.G.R	Ground Platform	Vacuum	I & C
Ion Source Water Flow	Ground Platform	Vacuum	I & C
Water Gun	HV Platform	High Voltage	I
Water Collector	HV Platform	High Voltage	I
Water Bore	HV Platform	High Voltage	I
Water Turbo	HV Platform	High Voltage	I
Gun Pirani Gauge Relay	HV Platform	High Voltage	I
Gun Platform Doors	HV Platform	High Voltage	I
Anode Platform Cage	HV Platform	High Voltage	I

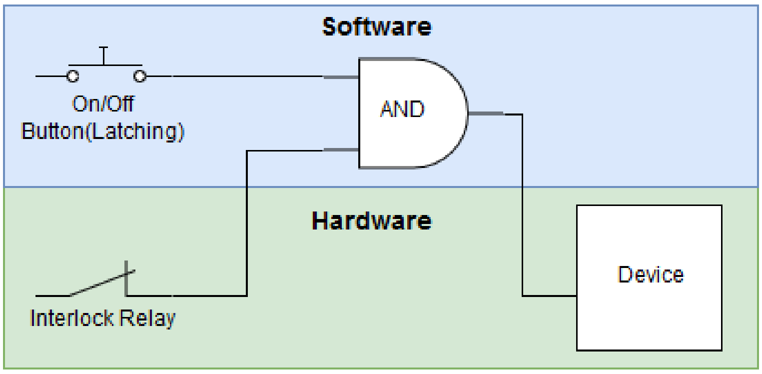
Interlock System's Operational Behavior

The interlock should be boolean values and a true should mean everything is ok and false when it is not ok. Their status will need to be easily accessible for the operator of the control system. The these interlock signals are important they should always travel as directly from the read signal to the PSU interlock control as possible.

Interlock System Under Normal Operation

When an interlock signal goes false every PSU that is interlocked with this signal should turn off. If the interlock becomes true the PSU should turn on again. Fig.3.1 illustrates how this function.

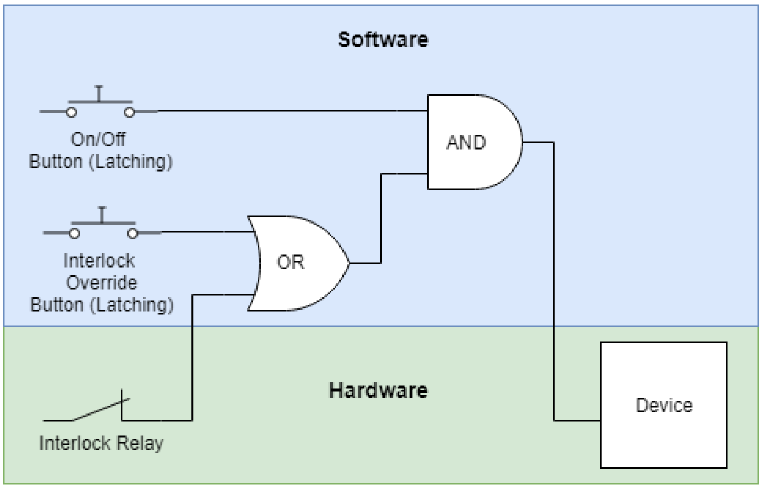
FIGURE 3.1: Interlock functional diagram



Operators Ability to Override Interlocks

For all the PSUs connected with a interlock signal it must be possible for the operator to override the interlock signal; turning the PSU on even if the interlock signal is false. This possibility is here because this is an experimental setup. This override does not override the actual interlock, but only enables that specific PSU to be turned on, even when the interlock is false. Fig.3.2 illustrates how the PSU control and interlock system must work on the control system.

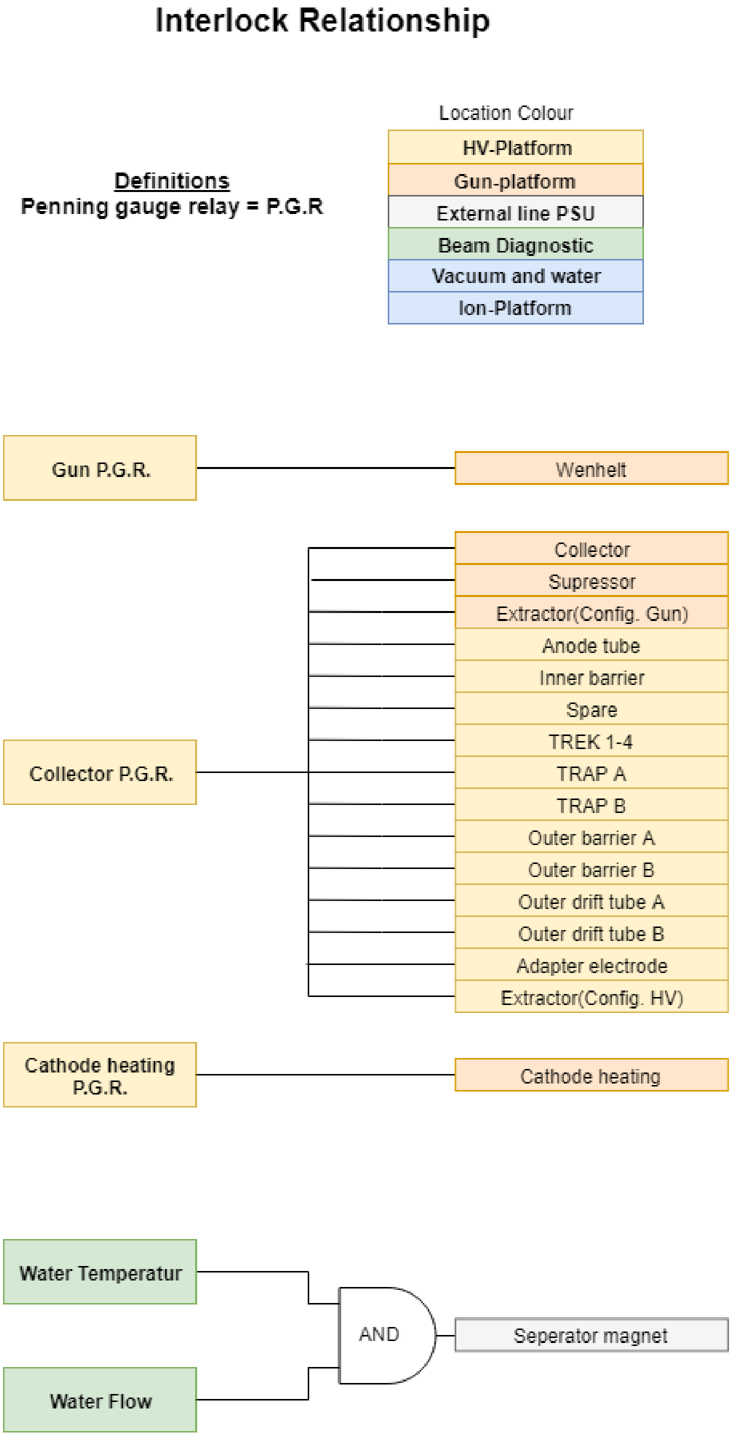
FIGURE 3.2: Interlock functional diagram with override

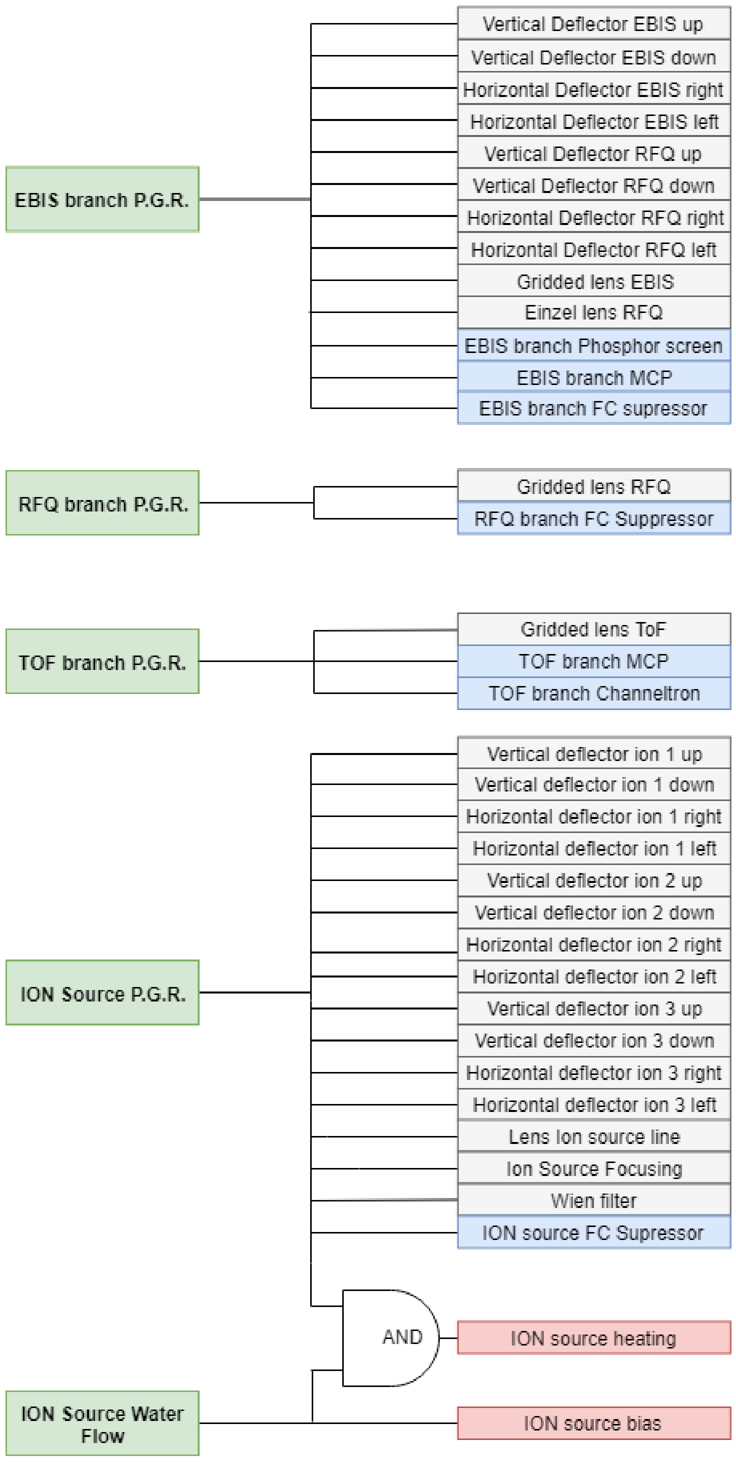


Interlock Relationships

One interlock might be control multiple PSUs. In fig.3.3 this relationship between the interlocks and the PSU can be seen. Interlocks on the left and the PSUs on right. The colour coding indication were in the system they are. The TwinEBIS test bench interlock system for the PSU has to follow this. This is the actual documentation for the interlock system so it includes a platform not discussed in this thesis. Ion-platform is a later addition to the TwinEBIS test bench and was added so the interlock system description would not have to be rewritten for the next test stage of the project.

FIGURE 3.3: Interlock and PSU relationship




Vertical Deflector EBIS up
Vertical Deflector EBIS down
Horizontal Deflector EBIS right
Horizontal Deflector EBIS left
Vertical Deflector RFQ up
Vertical Deflector RFQ down
Horizontal Deflector RFQ right
Horizontal Deflector RFQ left
Gridded lens EBIS
Einzel lens RFQ
EBIS branch Phosphor screen
EBIS branch MCP
EBIS branch FC supressor
EBIS branch P.G.R.
RFQ branch P.G.R.
Gridded lens RFQ
RFQ branch FC Suppressor
TOF branch P.G.R.
Gridded lens ToF
TOF branch MCP
TOF branch Channeltron
Vertical deflector ion 1 up
Vertical deflector ion 1 down
Horizontal deflector ion 1 right
Horizontal deflector ion 1 left
Vertical deflector ion 2 up
Vertical deflector ion 2 down
Horizontal deflector ion 2 right
Horizontal deflector ion 2 left
Vertical deflector ion 3 up
Vertical deflector ion 3 down
Horizontal deflector ion 3 right
Horizontal deflector ion 3 left
Lens Ion source line
Ion Source Focusing
Wien filter
ION source FC Supressor
ION Source P.G.R.
AND
ION source heating
ION Source Water Flow
ION source bias

3.5 Vacuum

The TwinEBIS test bench has a vacuum system since the tubes the particles travel through needs to be empty of particle as air would ruin the experiment.

3.5.1 Overview

There are three main types of hardware for the vacuum: Pumps, gauges and valves. Together they read, control and create the vacuum in the chamber. Fig.3.4 shows the layout of the vacuum system. You can see many similar names, but on different branches. The name indicates their function and their branch indicates were they are located.

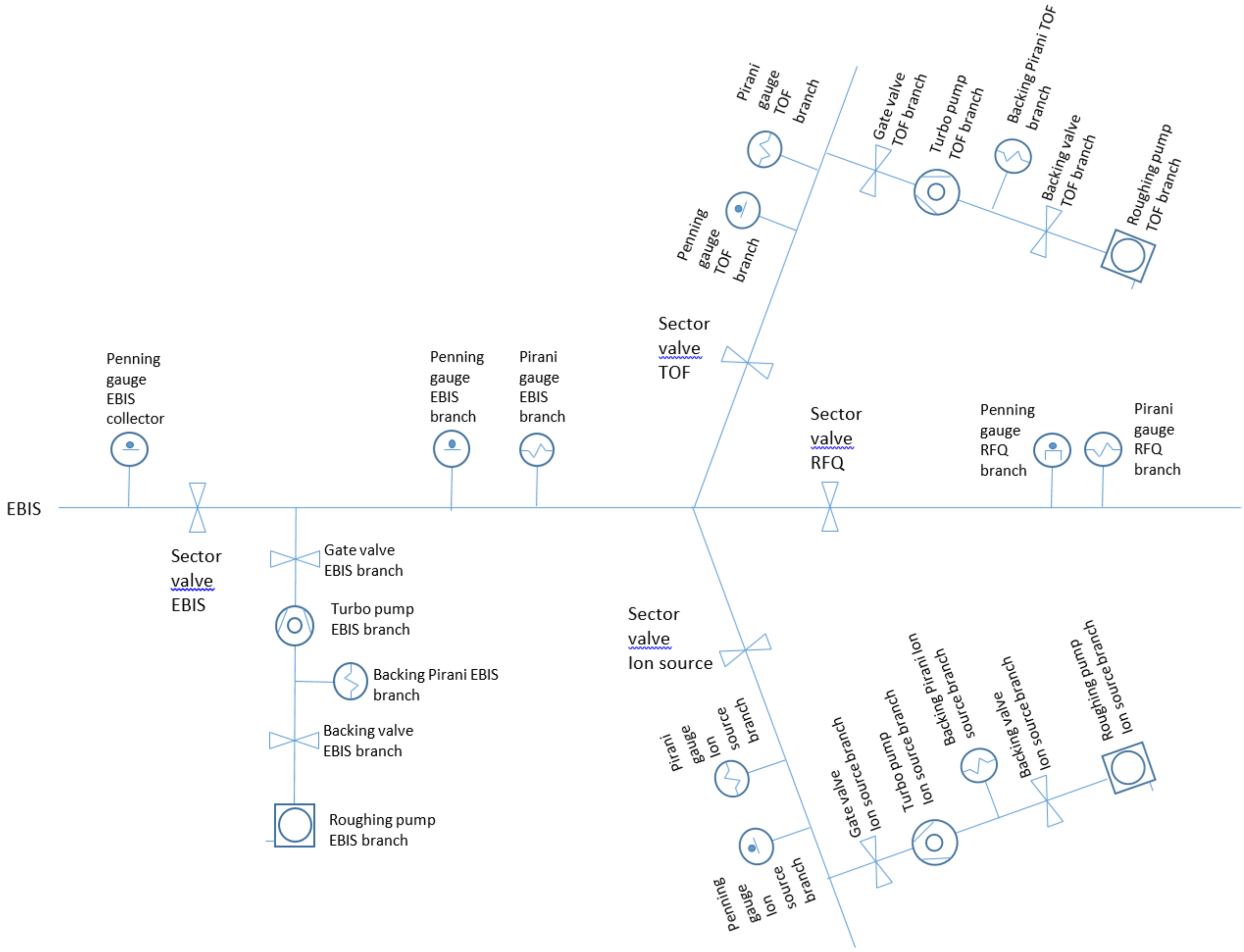


FIGURE 3.4: Vacuum Layout from Appendix C

3.5.2 Pump

The pumps function is to create vacuum. There is a total of six pumps, three roughing pumps and three turbo pumps. The job of roughing pump is to create the initial low pressure and the job of the turbo pump is to create and sustain very low pressure. They will either run or not run, there is not intermediate state. Their operation is controlled manually.

3.5.3 Valves

The valves job is to contain the vacuum to a closed area. There are a total of 10 valves, four sector valves, three gate valves and three backing valves. The backing valves controls the flow of air between the roughing pump and the rest of the system. The sector valve control the air flow between the turbo pumps and the system. The sector valve blocks the path the particles will travel from the rest of the vacuum system.

3.5.4 Gauges

The gauges function is to measure the vacuum in the different chambers. There are three types of gauges, four pirani, four penning and three backing pirani gauges. The backing pirani gauges are read with RS-232 while the rest are read via analog voltage level. The analog voltage is a raw signal and needs to be converted in software to be the pressure values. The function from the datasheet[8] of the penning gauge is shown in eq.3.7. U is the voltage read and A and k are constants that should be configurable by the operator.

$$Pressure[mBar] = A * 10^{k*U} \tag{3.7}$$

The function from the datasheet[8] of the pirani gauge is shown in eq.3.8. U is the voltage read and B and n are constants that should be configurable by the operator.

$$Pressure[mBar] = B * 10^{n*U} \tag{3.8}$$

3.5.5 Interlock System for the Vacuum System

There are some interlocks in place to restrict when a pump can run and when valves can be opened. It should be possible to override these interlocks for the operator from the GUI. This will be used when the operator wants to bypass the interlock for the hardware. If the power is cut the pumps should be turned off and the valves should be closed. Most of the valves and pumps has a interlock and each type of device has its own interlock requirements. The device in the vacuum system has to follow the requirements:

Gate valve

- Open if: Request open & ((Turbo pump speed > 80% & Pirani gauge <1E-7 bar) or (Gate valve Overridden))
- Otherwise closed.

Backing valve

- Open if: Request open & (Roughing pump running or Backing valve Overridden)
- Otherwise closed.

Sector valve

- Open if: Request open & ((Relay from Penning gauge upstream sector valve closed & Relay from Penning gauge downstream sector valve closed) or (Sector valve Overridden))
- Otherwise closed.

Turbo Pump

- Open if: Request open & (Roughing pump running or Backing valve Overridden)
- Otherwise closed.

Roughing Pump

- Open if: Request open
- Otherwise closed.

3.5.6 Visual aspect

The interface should use the vacuum layout as a background. When each component is pressed there should pop up a tab with the controls and info for that particular equipment and also the values of what is restricting it.

3.5.7 Measurement

There are two types of measurements that are needed for the TwinEBIS test bench ; Indicate the quality of the beam and the charge of the ions. The requirements for how the operator interacts with them is similar enough to have a section describing their common needs.

Handle and Interface with the Measurements

The measurements will not be processed or analyzed by the control software. The operator will interact with the data in in almost its raw form, but there are some operations that need to performed on the data.

- **Running Average:** Every consecutive acquisition values gets averaged and presented as a single sample.
- **Select interest area:** The operator must be able to cut away some of start and end of the signal as it will for the most part be empty and will just fill the graph without contributing any useful data.
- **Noise filter:** The operator must be able to set a minimum level for the signal, where all values below this set value will be converted to the set value. This is because values below this value is not useful, and will fill the graph.
- **Saving Data:** The data on the graph must be able to be saved. The data it is not automatically saved, but must be saved when the operator chooses too.

The measurements will have a high sampling rate and send data frequently and therefor the communication between the PC and the measurement device will need to be able to handle the large amount of data the measurements will produce.

Beam Quality

The beam quality is measured with Faraday Cups(FC). The FC is placed in front of the beam, which interrupts the beam and the FC produces a current that will be read by the hardware. This signal will then be sent to GUI, were part of the waveform will taken and averaged. This is true for both the readings from the picoammeter and the reading of the voltage drop over a resistor. The only difference is that measurement done in voltage needs to be translate into current. This means the operator needs to be able to input the specific resistor size used into a configuration file.

Time of flight measurement

The time of flight(TOF) will indicate charge of the particle to the operator, since the more charged particles will hit the measurement device earlier. When the charge hits it will create a current and this current will be sent through a resistor and the voltage drop will be measured.

The measurements will be average over N, but additionally this average over N will be added to the total numbers of hits over five minutes and 120 minutes. The main interest is the statistical average, so short lived anomalies can be ignored. With the average over a longer period of time the TwinEBIS test bench will indicate how consistently the electrons are removed.

Chapter 4

Selecting the Hardware and Programming Language

This chapter will explain which hardware and programming language was used to develop the control system for the TwinEBIS test bench and why they were chosen.

4.1 Prerequisites

The main implementation tool used was National Instruments (NI) Laboratory Virtual Instrument Engineering Workbench (LabVIEW), an integrated development environment utilizing the graphical programming language G. It has been chosen because is widely used in industrial test, measurement and control systems and is similarly used and supported at CERN. More details on why LabVIEW is the environment of choice is discussed in its own section.

The second reason for selecting NI's solution stems from the fact that some NI control and measurement equipment was already available and in use at the experiment installation and thus allowed for a cost efficient integration and extension of the system.

4.2 Advantages with LabVIEW

LabVIEW is a full stack development environment made for controlling hardware. LabVIEW fits the task because:

- It has a large variety of pre-made libraries for hardware control.
- National Instruments, the developer company behind LabVIEW, also manufactures and distributes reliable industrial controls that work well with LabVIEW.
- The integrated environment allows for code development and deployment on desktop, real-time and FPGA platforms. Code can be reused on different devices and pre-made inter-process communication mechanisms facilitate inherent parallelism of code sections with relative ease.

Full stack application development typically requires more time and coordination due to the amount of technologies and programming languages involved. In a non LabVIEW application a low-level hardware description language such as VHDL or Verilog could be used to program FPGA, C/C++ for the Real-Time system, C++/Java/Python for the backend of the user application and then HTML, CSS or JavaScript for the front end. Working in multiple environments with multiple related projects when developing an application is time consuming and harder to maintain.

4.3 Selecting Controllers

National Instruments delivers equipment that is made to work with LabVIEW, and easily communicate with each other. For this reason and the the reasons mentioned in last section almost all hardware chosen for the TwinEBIS test bench were purchased from NI. Where no NI equipment was chosen, there was either no identical product available or another manufacturer offered a more cost efficient solution.

4.3.1 NI's Hardware solutions

NI offers a wide range of hardware modules for signal conditioning, control and measurement applications. These modules are intended to plug-in to one of two types of controllers: PXI systems and CompactRIO (cRIO) platforms.

cRIO stands for compact re-programmable input output. It is a robust industrial controller running a Real-Time Operating System, a FPGA chip and modular slots for plugging in interface modules needed a specific application.

PXI stands for PCI eXtentions for instrumentation. It is a high-performance industrial controller capable of running a Desktop or a Real-Time Operating System and modular slots for interface cards suitable for control or acquisition applications. A PXI system consists of three types of parts: One controller, one or more modules and one enclosing chassis were everything is gathered. The chassis determines the bus system and the types and number of extension modules.

cRIO and PXI Modules

There is a wide range of what cRIO and PXI modules can handle. For example, analog signal, digital signal, TTL signal and interface with various communication protocol, and within a type of interface for a module, there is a lot of choice. As an example, for an analog input module, either voltage or current inputs are available. Other important factors to be decided are input ranges, AC, DC or mixed capabilities, acquisition speeds and amount of inputs and more to create a custom, tailor-made application solution.

There is a major difference between the cRIO and PXI which has been touched upon earlier: The PXI controller usually makes use of a desktop processor architecture making more suitable for general multi-tasking applications when compared to the cRIO platform. This also enables the PXI modules, often referred to as cards, to be more powerful than the cRIO modules. For example, some PXI modules feature sample rates up to 5GHz whereas a cRIO module is limited to 1MHz. Oftentimes, a cRIO is sufficient as a rugged, small and cost efficient solution for headless embedded industrial applications. When the cRIO is good enough for at task it is a better choice because it is more affordable than the PXI.

4.3.2 What equipment does the project already have?

The project already had a PXI and a cRIO, with various modules. These modules will be mentioned later.

4.3.3 Getting to solution

The requirements specification described in chapter 3 clarified which hardware would be suitable. On the high voltage platform and the ground platform sampling rate requirements ranged up to 2 MHz. As the highest sample rate for a cRIO is 1 MHz, a PXI controller and corresponding hardware was needed for those platforms. A PXI would be good enough to do every task, but using it for every task on those platform would not be cost effective.

The gun platform requirements can be met by a cRIO, but since it is on a separate platform it needs its own controller. This means that minimum requirement would be three cRIOs, one on each platform, and two PXIs, one on the ground platform and one on the high voltage platform.

4.3.4 Solution

With all the information given at this point and taking a new look at table 3.1 from the requirement chapter, the hardware solution can be selected. The exact cRIO and PXI type will be discussed in a common section after this.
There did not exist equipment from NI of interest any were close to 5Hz sampling rate, everything was faster. The selected hardware meets or exceeds the requirements.

Gun Platform

The types needed are analog input, analog output and relay modules. The NI 9205 and NI 9264 modules operate at $\pm 10V$ and have a 16bit resolution within this range, exceeding the required 14 bit resolution. The NI 9485 relay module can take up to 1A per channel.

Interface Type	Interface #	Interface/Module #	Module #	Name
Analog Input	12	32	1	NI 9205
Analog Output	12	16	1	NI 9264
Relay	6	8	1	NI 9485

High Voltage Platform

This high voltage platform will have a PXI and a cRIO controller. The cRIO requires modules for analog input, analog output, relays and digital input.

Interface Type	Interface #	Interface/Module #	Module #	Name
Analog Input	23	32	1	NI 9205
Analog Output	23	16	2	NI 9264
Relay	13	8	2	NI 9485
Digital Input	11	32	1	NI 9425

The project already had the PXIe 6713 card a analog output card with TTL, so reusing this was a priority. The PXI needed analog input at 2MS/s, analog output at 2MS/s/Ch and TTL at 2MS/s/Ch. The PXIe 6713 is fast enough for the requirements for the analog output and TTL.

Interface Type	Interface #	Interface/Module #	Module #	Name
Analog Input	5	8	1	PXIe 6713
Analog Output	5	8	1	PXIe 6361
TTL	3	8	1	PXIe 6713

Ground Platform

On the ground platform 38 relays were needed. This would require five of the cRIO modules to fit, which would raise the cost of the installation. Instead, a modular solution with external relays driven by a digital output cRIO module was chosen. These relays could take up to 6A and could be used for all the relay needs regardless of the current draw as the max current draw was 0.25A

Interface Type	Interface #	Interface/Module #	Module #	Name
Analog Input	41	32	2	NI 9205
Analog Output	36	16	3	NI 9264
Digital Output	38	32	2	NI 9477
External Relays	38	1	38	G2RV
Digital Input	33	32	2	NI 9425
RS232	3	4	1	NI 9870

The second card the project already had was a NI 5751R card. This is a very fast analog input acquisition card reading at 50MS/s/ch with 12 bit resolution on eight channels. This will be sufficient to satisfy the requirements for the five inputs needing 2MS/s/ch with 12 bit resolution. The remaining channels are five analog input and five analog inputs at 100kHz/s/ch and one TTL at 2MS/s/ch. There are cRIO cards that would be fast enough, but they only have four inputs, meaning four modules would be needed. This would be more expensive than buying one PXI card with eight analog inputs, eight analog outputs and eight TLL connections. In total two cards were chosen.

Interface Type	Interface #	Interface/Module #	Module #	Name
Analog Input	5	eight	1	NI 5751R
Analog Input	5	8	1	PXIe 7841
Analog Output	5	8	1	PXIe 7841
TTL	1	8	1	PXIe 7841

GPIB and RS485

Most of the cRIOs controller come with a RS485 interface and most PXIs controllers come with GPIB interface and therefore no additional communication modules are required.

PXI and cRIO controller

The project had a cRIO controller and a PXI controller. The cRIO was cRIO 9081, an older model, so using it for the least demanding task which was the gun platform control was chosen. The PXI existing was good and could be place on either platform, but was choosen to be used on ground.

On the ground platform there was a total of 10 cRIO modules needed. A cRIO can hold up to 8. It was natural to divide it among the system. Bundling the Beam diagnostic and Vacuum to on cRIO and the Beam Optics to one cRIO worked out so this was chosen. The high voltage platform had five modules in total and could use a single cRIO. The most affordable controller that had RS485 and was good enough was the cRIO 9045. It was also new and will be supported for a long time. For these reason it was selected for the three cRIOs that had to be bought.

The PXI system for high voltage platform got a chassis with eight slots and a controller that was fast and enough memory.
The first table in appendix B is the same table used for the requirements, but extended. The new categories were: controller, solution, comment and ownership status was added. This table made it clear what NI equipment was required to facilitate the hardware needs. More details on the cRIOs and the wiring of the patch panel can be found in appendix E.

From now the controller will be referred to by their abbreviated name because their full name would increase the sentences length without adding any information. For the PXI and cRIO on the high voltage platform the abbreviated name is HV cRIO and HV PXI. The cRIO for beam diagnostic and Vacuum will be BDV cRIO and the cRIO for beam optics will be BO cRIO. The gun platform cRIO and the ground platform PXI is so short it does not need an abbreviation, but the platform part will be omitted.

4.3.5 Order list

The second table in appendix B was derived from the requirements first table in the same appendix. Here, the spare connections are clearly stated the amount of spare available on each platform for each type of interface. As a test bench set up, a spare availability of 33% was deemed sufficient. In addition to everything discussed in this section, PSU to power the cRIOs and a BNC breakout-board for one of the PXI cards were added.

4.4 Selecting a Computer

Both the development and later operation computers were similarly powerful and running a Windows 10 Operating system.

4.5 Selecting Communication Hardware

The NI equipment and the PC all provide an Ethernet interface which facilitates the flexible industry standard TCP/IP. Ethernet interface can facilitate many different communication protocol, most commonly used with TCP/IP which is the backbone of the world wide web.

4.5.1 Infrastructure

When multiple devices have to communicate with each other with TCP/IP there needs to be a router or switch connecting them. A switch sets up communication between the devices which is enough for the TwinEBIS test bench. There are seven devices and one connection could be used to connect it to the internet or an intranet. This mean the switch has to have a minimum of eight connection, but should have more as it is certain that there will be more devices added. All of the devices has Ethernet interface and is made to work with TCP/IP. This setup would give the network topology seen in fig.4.1.

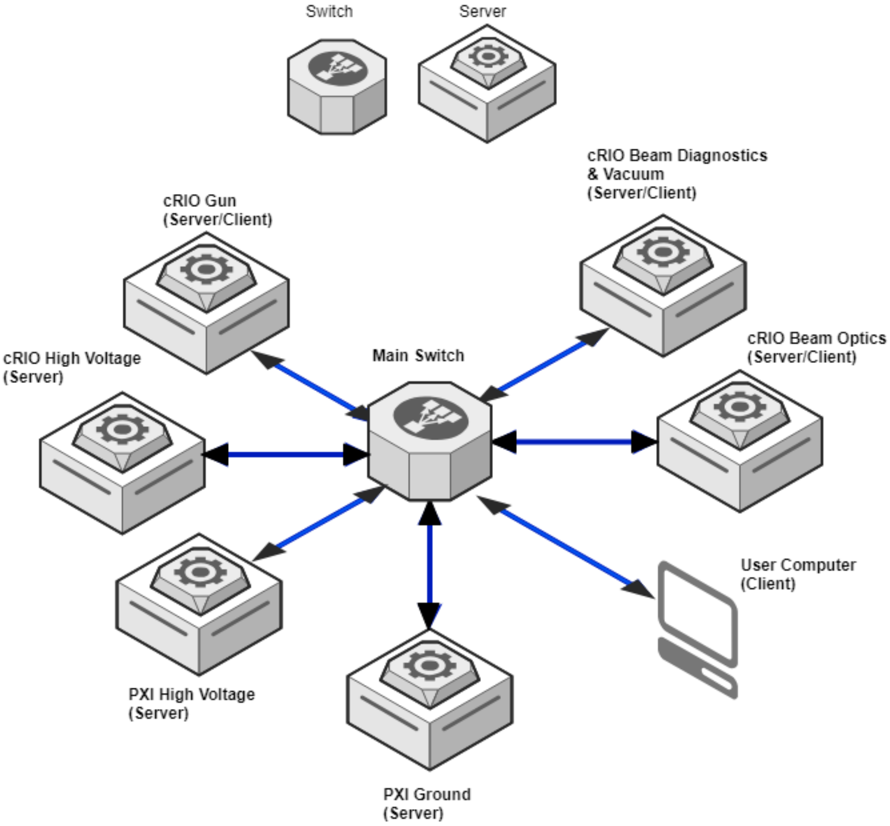


FIGURE 4.1: Network Topology

4.5.2 Network Data Rate Considerations

Switches are rated for their speed and this value almost always increments by a magnitude. 100Mbit/s, 1Gbit/s 10Gbit/setc. For this application the largest data type is the waveforms with a sampling rate of 2MS/s. If these continuously sends their data and store their values in arrays with the data type double this would require 128Mbit/s/channel.

$$64bit * 2.000.000S/s = 128.000.000bit/s = 128Mbit/s$$

This would allow a total of eight channels on the 1Gbit/s router if there was no header with the package or any addition data with the waveform. A TCP/IP package always comes with a header and the same goes for the waveform which would mean realistically that seven would be the maximum. Standard 1 Gbit/s network hardware was sufficient since all channels will not run at full speed. The data will be decimated and all channels will not send data all the time.

4.5.3 Accounting for the Voltage Difference

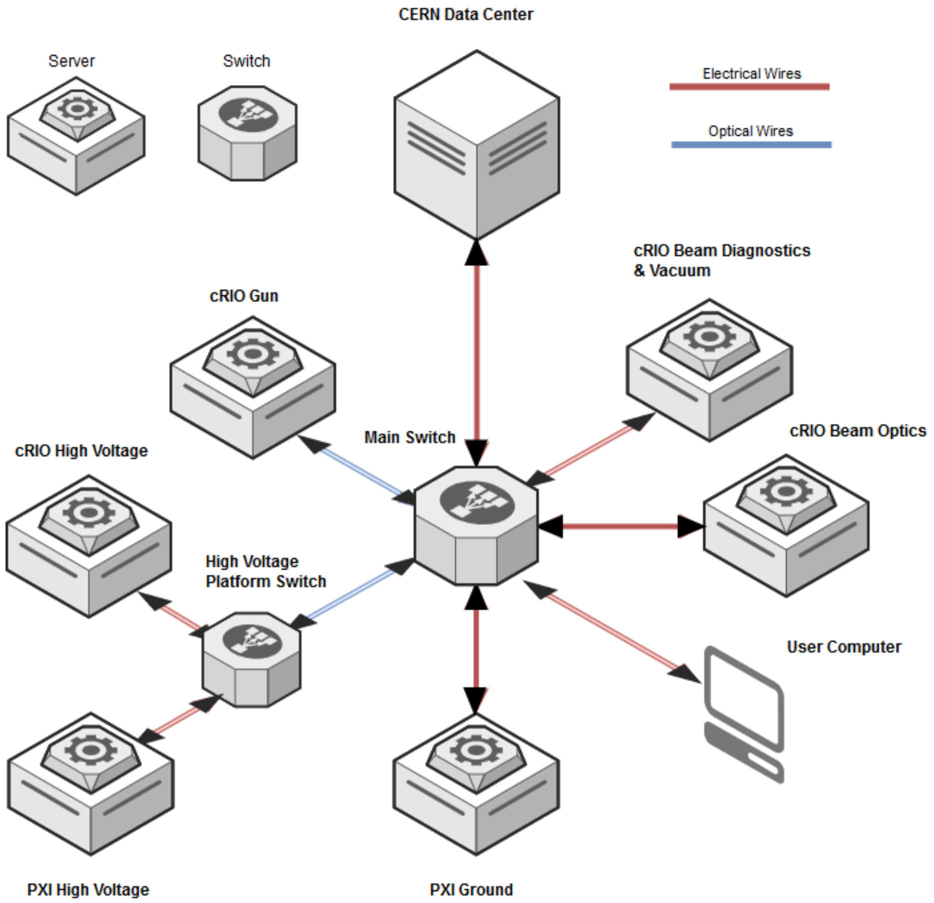
The TwinEBIS test bench is spread out over three platforms with different voltage levels. This complicates the communication as additional media converters are needed to enable the communication. Multiple voltage levels is not uncommon at CERN and the go to solution is to convert the electrical signal to optical fiber and back again. Optical fiber has the advantage of being fast and readily available.

Ethernet over Voltage Difference

TCP/IP uses Ethernet as a hardware layer so a Ethernet to fiber solution was needed. This is very common making it easy to find one operating at 1Gbit fiber. The EKI-2741SX [3] media converters and fibers were chosen because it fits the requirements. These were needed between ground and the high voltage platform and ground and the gun platform. To give both the HV PXI and the HV cRIO a connection an additional switch was added on the high voltage platform.

The addition of equipment changed the topology. Fig.4.2 reflects this change. Colors are added to indicate which connection has to convert to fiber. The CERN infrastructure was also added as TwinEBIS test bench would want be connected to the rest of the CERN network since this gives the computer access to all data contained at CERN. The final network topology figure should reflect this connection.

FIGURE 4.2: Network Topology



Triggering over Voltage Difference

The trigger signal sent from HV PXI to the ground PXI has to have a jitter of 0.5us or less and has to travel between two voltage potentials. Normally a TTL signal is used as a trigger. If there was no voltage difference the PXI would be connected via a cable that would cause no jitter, but only a very small propagation delay. The PXI do not have a optical fiber trigger functionality on them. There exist PXI cards which add this functionality, but these are very expensive. Instead the HV PXI and the ground PXI will trigger normally, but with a TTL to fiber converter and fiber to TTL between them.

A jitter is another word for relative precision of consecutive triggers. If it is a fixed offset on signal it is propagation delay, and this can be calculated away. Meinberg [5] was selected, because it fit the requirements. It had an non deterministic conversion rate, but it had a minimum speed of 10Mhz. It worked with devices that ran on 3.3V and 5V. When the device was test it showed a propagation delay of 50ns and less 10ns of jitter, which was far better than required.

4.5.4 Hardware Topology

The voltage differences required the system to be composed of multiple devices. Proper documentation ensures easy adaptability for future maintenance and extensions. Fig.?? provides an overview of the current implementation state of the communication system, media connections and communication directions. If there are no arrows the communication goes both ways.

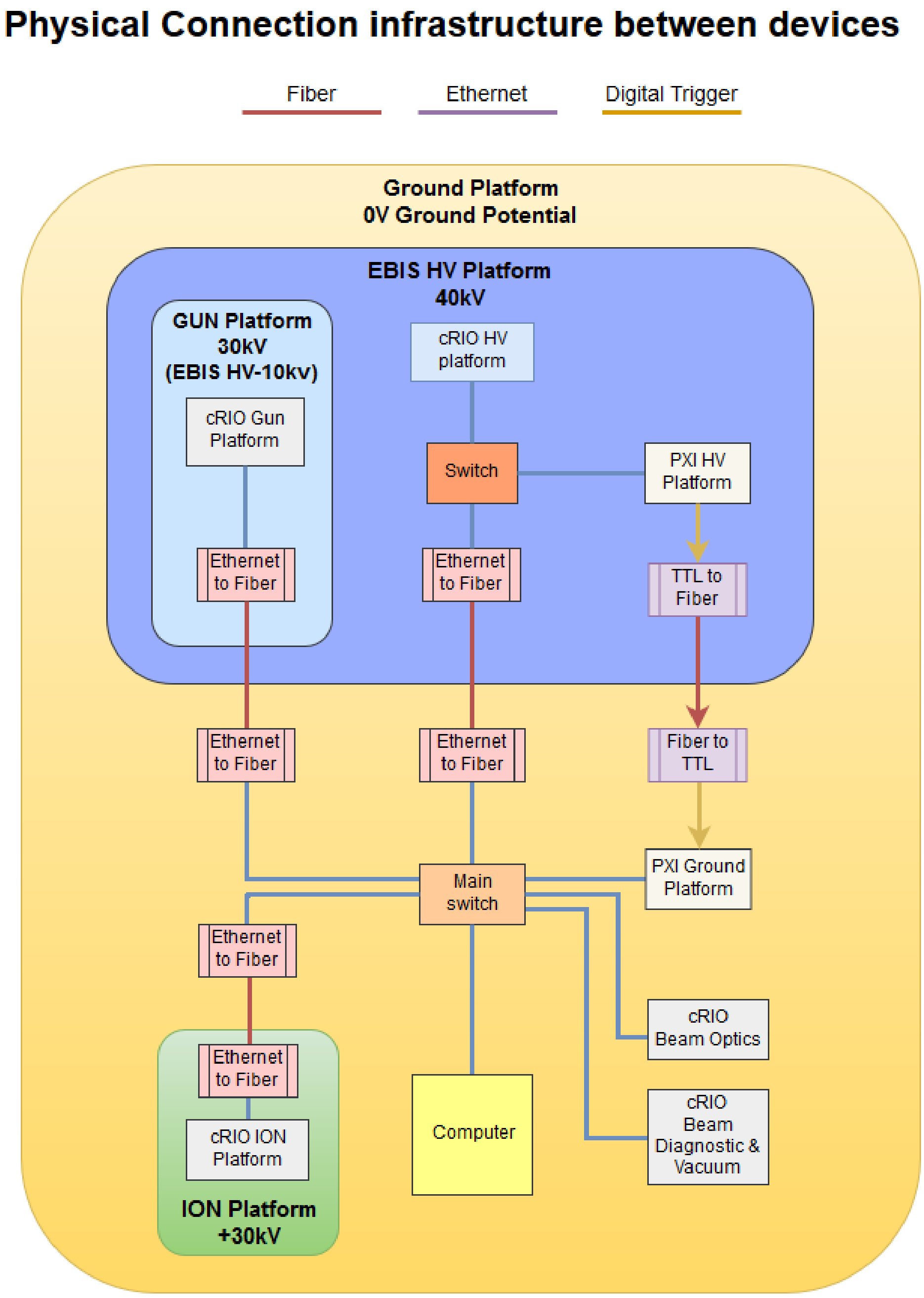


FIGURE 4.3: Hardware Topology

Chapter 5

Communication Framework

5.1 Creating a Universal Communication Framework

This chapter will focus on the design choice for each individual part of the communication framework and how they work together. The communication framework consists of three parts: the package type, communication protocol and the communication manager.

5.2 Abstraction and Classes

This section will give a short explanation of some vital concepts for this text. The explanation will not go to much detail but will give information about the important aspects for understanding this thesis.

5.2.1 How Abstraction is Helpful

To be able to control a complicated system like the TwinEBIS test bench one needs to compartmentalize the functionality. This will make it easier to develop, maintain and test since it is closed off. Testing and changes can be done to the specific part without having to involve the rest of the application which makes it easier to find error and correct them. This is the concept of abstraction, to compartmentalize something and generalisation it to a closed off and independent system.

5.2.2 Classes

Classes is a part of object oriented programming. It is a grouping of data and functions that fit under a theme. Function in a class is called a method.

- **Inheritance:** A class that is a child of another class has access to the parent class data and methods.
- **Override:** A child can choose to use the parents method or override them fully or partly by making their own version. If a class has multiple children they can each have their own version of that method so when a child uses the parents method it uses its own functionality, rather than the parent functionality.

5.3 Communication Protocol

It was decided early on that CMW would be the main communication protocol used for this application. CMW is standard used at CERN and is built on TCP/IP with additional functionality. The problem with CMW is that it only works at CERN facilities. If you use CMW in an application and this application moves out of CERN, it will stop working. For this eventuality the physicist request that the application would be flexible enough to allow other protocols to be used in the future without having to re-write a lot of code. In addition to this the CMW protocol implementation on LabVIEW was split into two libraries: CMW client and CMW server. This meant they need individual encapsulation.

Using a class to abstract the different protocols would be a good option since there could be a common protocol parent in which all of the different protocols could be a child of. By generalising how to operate the class and how to configure it the same program could use the parent methods and depending on which child used on this method. With this approach changing between one protocol to another would be simple and if any new protocol would be added, it could be a new child of the protocol class. The hierarchy of the communication protocol class can be seen in fig.5.1.

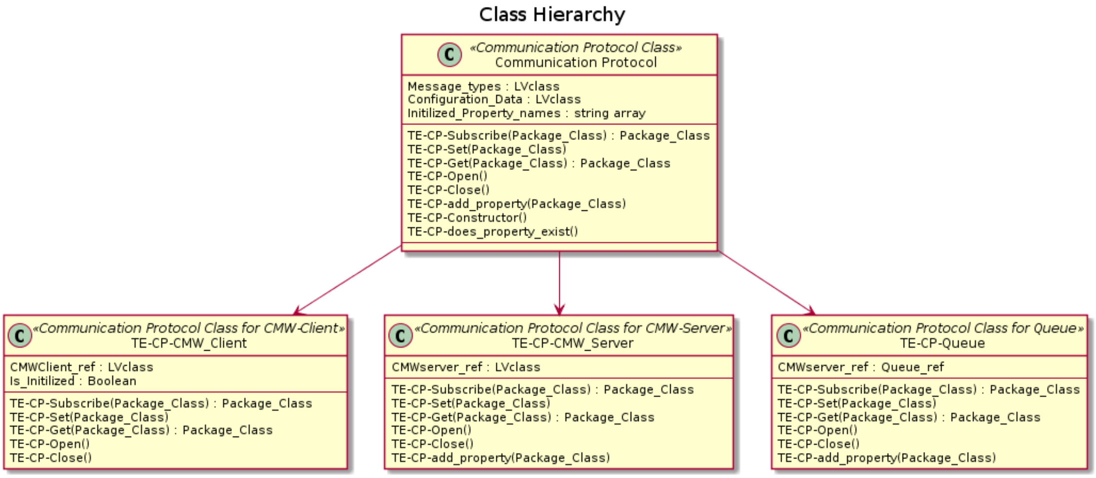


FIGURE 5.1: Communication Protocol Hierarchy

5.3.1 How it Works

The hardware protocol has five methods that are used by others: open, close, set, get and subscribe. Every child protocol has to have their own override of these function and in them keep the code that fulfils the task. If this class is used with the parent there will be an error since the parent has no functionality in those functions.

Open method needs to contain everything needed to initialise the communication. If it is a server this is to set up a server with all the correct services. Close needs to stop the server and its services. When a class is initialized one can use the set, get and subscribe function. The set function takes an input data and post it on the server. The get gives the latest data. The subscribe stops the program from continuing until there is new data or it times out. If there is new data it give this data or else it gives out empty data.

5.3.2 Dealing with Multiple Data Types

A server can host multiple service with different data types. This means input and output of set, get and subscribe methods needs to be generic enough to allows any data time. These function also would need an addition input for selecting the specific service one wants to get from the server, this functionality could be a part of the generic data package. For this application the generic data type used was the package class and in it there is information on the type of data it contains. Using the package type class allows the communication protocol to have only one type of input and output.

5.3.3 Additional Features

When choosing which child to use in LabVIEW one usually have to manually place a block from the child of choice. This would make the setting up of servers and client static as each application would have to be manually coded. To solve this a method that programmatically creates an instance of the specific child from a string was created.

5.4 Package Type

During development of an application, especially larger application it is hard to know exactly which data types are going to be used for specific communication. Even if one plans it well it often happens that a cluster of data types is missing one unforeseen data type and if you have no system in place to propagate a change like this, it would require a lot of work since one would have to change every place this cluster is used in the application. This can be negated by using type definitions, which defines the content and every one that uses this data takes the information from this type definition. If the type definition changes the change propagates to all of them. This solves the problem for specific cases, but if one wants a function to take in multiple data types or it is apparent that the data type can change often, even a type definition would not be sufficient to keep up. This can be solved by abstracting away the whole data type aspect. For this application this was solved by having a package class

5.4.1 How it Works

Almost all of the functionality is contained in the parent, but each child needs to have two methods and a type definition. The type definition is a cluster with all the data types that will be needed for a specific package. This type definition is also the private data of the child class. An example: a type definition for the PSU levels could contain two array of doubles, one for voltage and one for current, where the position of the number indicates which PSU it is.

One of the methods this PSU level package would need to have was an initialisation method that would be an override of the parent. This method does two things. The part that is unique for the package type places its unique type definition into a variant data type, which is just a data type for any data type. The second parts that is common for all is that the parent class method takes the name of the type definition in the variant and stores it with its private data. The generic package now contains the information about which package it facilities. Reading this name is a parent method which means the package name can be accessed without any knowledge about the specific package.

The second method it needs to have is a method which converts the variant to the correct data type. This is only needed when the data will be used and is not an override of a parent method. This method also checks if it is the correct data type before converting and creates an error if it is not. This error is used to stop the propagation of data and highlight where the mistake was made.

5.4.2 Other Uses

The package class is not only used by the communication framework. The application on the cRIO, PXI and PC also uses the name of the package to decide which method to use on it. This ensures that a package is not sent the wrong place when running.

Most data passing methods around in the application uses the package class to pass data. This gives the flexibility that one could always change package because one does not need to be concern with the specific data type. Most methods that use the package class to pass data only passes it without reading it, they do this mostly because not every part of an application can communicate directly with each other, so it is passed along, or they read the information about the package and passes it on.

In fig.5.2 the private data type and the two mentioned methods are shown. In addition the method to write the data into the class and the method for getting the package name.

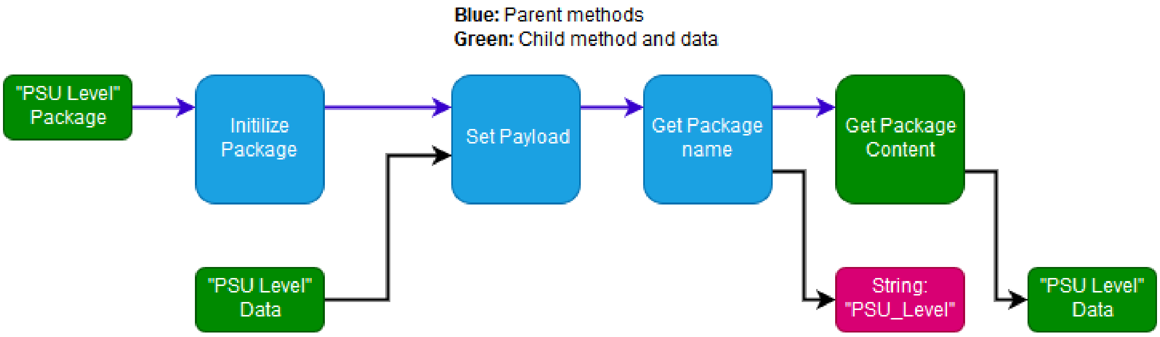


FIGURE 5.2: Package Class essential features

5.4.3 Additional Features

The package class also has a method which creates an initialized instance of a package type from a string. In the private data of the parent there is information about which device sent it and who it is for. This information is so far used to diagnose errors and for postal service like routing on the PC.

5.5 Communication Manager

The protocol and package class would work on their own, but setting up multiple services, subscription and so forth would require a lot of more static coding. The hardware manager purpose is to make this configurable.

5.5.1 How it Works

When an application starts the communication manager it initialises it with the configuration for all the device and the name of the device it is running on. This configuration contains one common section which has the IP/host-name of all the devices in the network and the specific configuration for each device. The specific data contains three pieces of information.

1. Which protocol to associate with which device.
2. Which services it should host.
3. Which subscriptions it should have from whom.

If the device is a host it starts by initialising the server with all the services. It then start all the subscriptions and initializes them if they do not host them themselves. The subscription are started in parallel to the main function so they do not block the process. When they receive new data they send them to the main process. This sequence is shown in block form in fig.5.3.

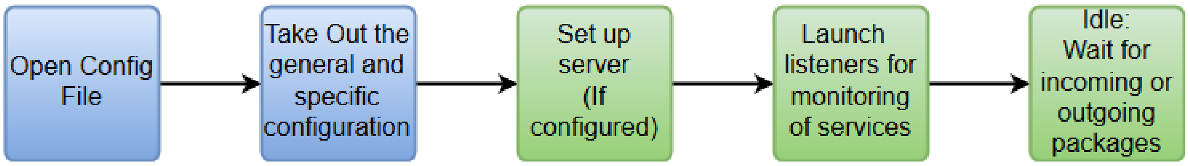


FIGURE 5.3: Start up actions of the communication manager

While the manager is running it actively only does two things. Re-start subscription to server it does not have a connection to, pass data from the application to a server and from a subscription to the application.

5.5.2 Configuration

The configuration for the communication framework is created from the application and written onto a file. This file is distributed on all of the devices and opened on start up of the application and given to the communication manager. This configuration file holds all information for setting up the communication on all the devices. Changing the protocol or which device to subscribe what from is done by editing the configuration file and restarting the devices. An improvement to this feature would be to only have to restart the communication manager to propegate the change and not the whole application.

5.5.3 Additional Note

It is possible to use the protocol directly and still be part of eco-system the framework gives. This could be beneficial in a smaller application, but all the application for the TwinEBIS test bench need the flexibility the communication manager gives it.

5.6 Communication Concepts

5.6.1 How it Works

When a server is set up it is set up with some services. These could be PSU level, gauge level, pump status etc. The server can only handle service it has setup. When a service is up the server or a client can choose to set, get or subscribe to one of these service. When the data is set, the existing data on that service will be replaces by the new data. When a get operation is done the latest data is gotten from the specific service and server. When subscribing to a service from a service the process will halt and wait until the server notifies that there are new data or it times out. If a server subscribe to its own service it does not notify itself when the server sets data on the server, but it notifies any client subscriber. When a client sets new data on a server everyone is notified. The subscription can stop up process and is the reason they are mostly done in parallel to other processes. The data is always stored on the host of the server and any communication with a service will always go through which ever device that hosts it.

5.6.2 Use of Communication in the Rest of the Text

In the rest of the thesis the details of the communication will be reduced. It would harder to focus on other points if the details of the communication is always metnioned. Instead the communication will be referred to in the following way: "X receives data A from Y" or "Y sends data B to X". This will be a generalisation, but it will keep the focus intact.

Chapter 6

Control System Software Solution

An important goal for the development of the cRIO and PXI control system is to make it easy to maintain, flexible and quick to develop while still fulfilling all the requirements. This is a test bench and changes will be done at some point, small and large, so flexibility is key. These properties do not always help each other, creating a very flexible code could take a lot longer to develop.

Being able to reuse the communication framework saved time. Another way to reduce the time spent on the systems development and maintenance is to create two application instead of six. Having one application for all the cRIOs and one for both the PXIs instead of having an individual control system for each controller.

6.1 cRIO

The cRIO controls most of the equipment that is designated as slow from the requirements. This includes static PSU control, Vacuum control and moving the piston for measurement.

6.1.1 Inside of a cRIO

A cRIO can be viewed as something that consists of two components, Real-Time(RT) controller and the FPGA. The RT and the FPGA are the brains of the cRIO. How the cRIO is programmed decides which of them is in charge. In this application the RT is in charge and the FPGA is a slave. The difference between them is that the RT can communicate with the outside world and the FPGA can read and write to the modules. The RT can be compared to a very powerful micro-controller or a weak PC. It is very flexible and can do most operation. What the FPGA can do is very strict, this is because what is programed is how a network of transistor should be connected. The most prominent limitation is that all things stored has to have a predefined size, no dynamic processes in run time and certain data types are not recommend.

6.1.2 Architecture

- **FPGA:** read and write to the modules, and for this application it is only used to convey and sort the data between the hardware and the RT.
- **Hardware protocol:** abstracts away the FPGA control on the RT so that any changes that is done with controlling the hardware and FPGA will not effect the rest of the application.
- **Hardware manager:** controls the hardware protocol. The hardware manager does not know how to communicate with the hardware, but it knows when, why and what to communicate and which function a specific cRIO has.
- **Communication manager:** enables communication to other devices. The details has been explained in the last chapter.
- **Vacuum control:** controls and monitors every part of the vacuum system. It is similar to the hardware manager in that it knows when, why and what to tell the hardware to do, but not how. This could have been a part of the hardware manager, but as it will only be on one device and controlling the vacuum is intricate, it got compartmentalized away and functions more like an extension of the hardware manager.
- **Root:** binds everything together. It starts everything, monitors the system and chooses were packages from the communication manager should go.

In fig.6.1 these individual elements are separated and who they can directly communicates is marked with lines. The Hardware manager is split up to indicate there are four option, they should never run at the same time.

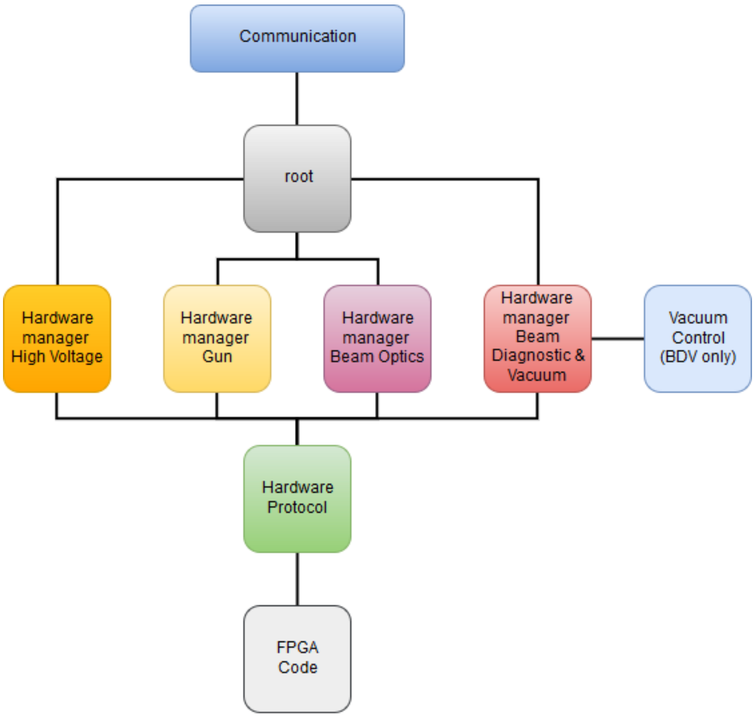


FIGURE 6.1: cRIO architecture

6.1.3 FPGA

Purpose

The FPGA could do a lot more, but in this application it mainly passes data between the modules and the RT, since the RT cannot access it directly. There are four separate cRIOs with different modules, its job is also to set the values to the correct pin on a specific modules that is part of the cRIO it is running on.

Functionality

The RT and FPGA communicates through something similar to a variable. The FPGA writes and the RT reads from the variables associated with read values, and the RT write and the FPGA reads the variables associated with set values. There is a variable for each type. Current level, voltage level, TTL, gauge level etc. and they are dividing into read and set, if needed. The values are directly associated with the a module. The FPGA reads a variable and writes it immediately to the right pins on the module which turns it into physical values. This is asynchronous as the FPGA writes it as fast as it can since checking and waiting for a new data would be slower.

Fig.6.2 shows the LabVIEW code necessary to read the physical value of a current via the FPGA and an Analog Input module. They are in a special LabVIEW case structure called conditional disable. It works like a case structure, but instead of not doing the code in the other cases it ignores it and does not compile it, similar to #ifdef #ifndef in C. One of them is gray and the other one not because of the one that is grayed is conditionally disabled and will not be compiled. They are part of the same case structure. Regardless of what is compiled they always write to the same variable which the hardware protocol reads from. This is why the variable is outside of the case structure

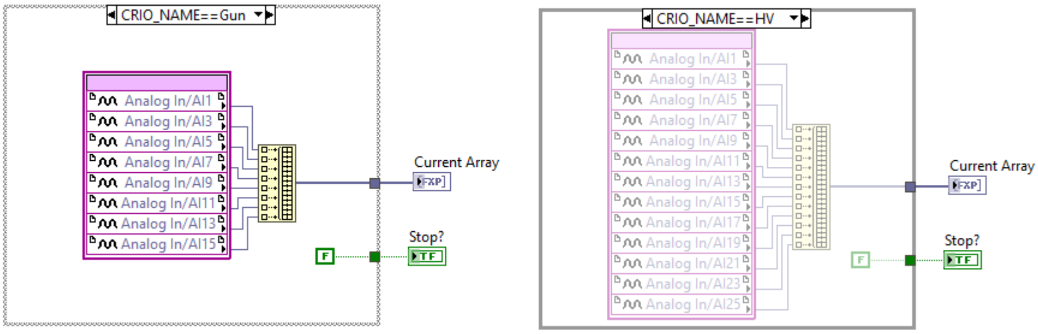


FIGURE 6.2: Read current values from Gun and HV cRIO

The requirements for the PSU interlocks is that it should travel as short distant as possible. The HV cRIO and the BDV cRIO reads the interlocks locally and therefor the interlock data read by the FPGA is written directly to the variable for the interlock.

6.1.4 Hardware Protocol

Purpose

The hardware protocol abstracts away how to operate the hardware so others who need access to the hardware can do so without having to know how. This abstraction also stops any change with the hardware to affect the rest of the system and makes it possible to replace the hardware code with simulation code so the application can be tested on a computer.

Functionality

The hardware protocol is a class with a child for simulation and another one for the FPGA. This gives the ability for the hardware manager to only have a common set of function to control the hardware, making the change between simulation and FPGA control seamless. A new child can be added if different hardware types gets added at a later date.

The FPGA variables are contain in methods of the hardware protocol and grouped together in such a way the user of the method can set more general values and not worry about which pin goes to what. One of these methods sets the level for the PSU. The caller of the method gives the values and inside the maximum voltage check, scale to control voltage, Polarity switch and ramping is done, if needed. The specifics of these methods is discussed in the static PSU part of this section.

6.1.5 Hardware Manager

Purpose

The hardware managers purpose is to know what data should go were, how to sort it and controls the update frequency. The cRIOs control different hardware and the manager know what each individual cRIO is capable of.

Functionality

The hardware manager is a class with four children, one for each cRIO. The root is in control of which of the hardware manager is started. The parent class has most of the functionality. One of these things is containing an instance of the hardware protocol. With this it open, closes, read and writes to the hardware. All incoming request for setting values goes through the manager were it sorts the data and uses the correct hardware protocol method on it. The protocol only works with standard data types while the manager packs and unpacks packages going to and from the communication. The most important part is that each of children knows what the cRIO it controls is capable of.

6.1.6 Root

Purpose

The purpose of the root is to initial the application the correct way according to the cRIO it is running on. When it is running its job is to sort the incoming and outgoing packages so that they go were they should.

How does it do it?

When the application starts the root is the first part that begins. After this the communication manager and hardware manager is started. The root can read which device it is one and gives this information to the communication manager so it can get the correct configuration. The root also uses this information to start the correct hardware manager.

When a package is received from the communication it contains information on the type and who sent it. Based on this information the root decided which of its methods to call on it. For each package type the cRIO would receive there is a root method. In these method there is code for what to do with the package. Most of them just forwards it to the correct hardware manager method, but some can restart the cRIO, update the configuration among other things.

Since the cRIOs do not set values on other servers all the outgoing packages just gets forwarded to the communication manager. The root also regularly updates a service called heartbeat to signal that it is still running.

6.1.7 Vacuum

Purpose

The vacuum control system keeps track of the status of the pumps, valve, and the interlocks and handles the requests from the operator. The reason the vacuum control system is separated is because it is only used one on cRIO and there was enough functionality that it is cleaner to separate and compartmentalise it. This also makes it easier to develop and maintain.

Functionality

The status of valves, pumps and gauges is continuously shared with it by the hardware manager. It process this information and distributes this information as fast as it gets it. When a operator request is received by the cRIO it is sent to the Vacuum control system where it is evaluate against the interlock and sent to the hardware manager if it is approved.

Interlock

The vacuum system stores all the data relevant to the vacuum interlock so that it always knows the latest status and can use this when controlling the vacuum system. When a request to turn on a pump or open a valve is received it will check the interlock condition for that device and accept the request if the conditions are met. The request will then be forwarded to the hardware manager which will set the hardware.

Controlling the Vacuum System

In fig.6.3 the operator interface to the vacuum system is shown. From here the pumps and valve status can be set, read and the pressure can be read. The layout of the GUI is a copy of the vacuum layout and the controls have the correct symbol according to if they are turbo pumps, backing pump, gauge or valve. This gives the operator a clear picture of what is going on.

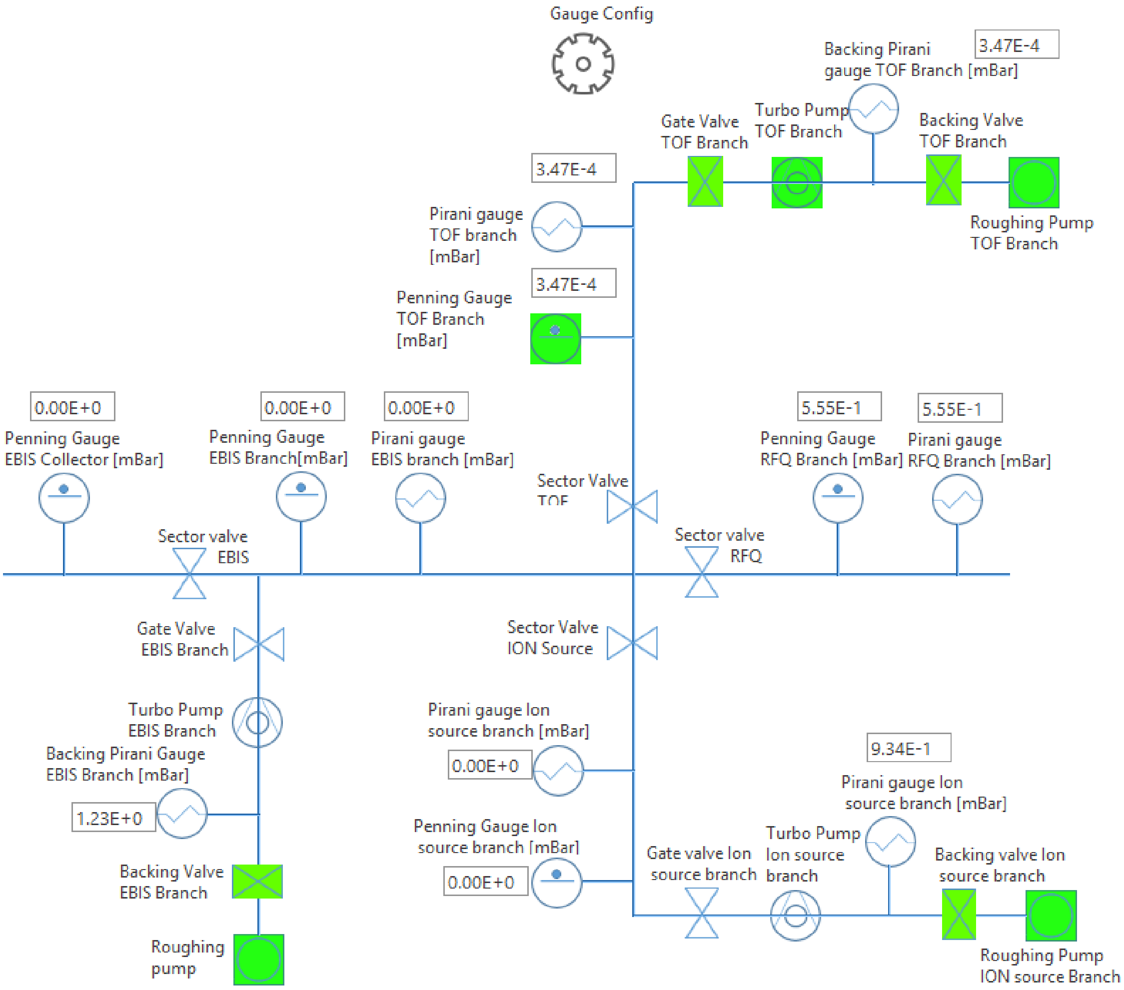
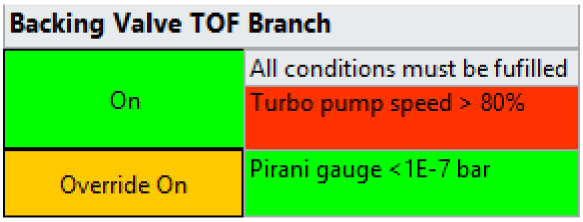


FIGURE 6.3: Vacuum GUI

When a pump or a valve is pressed, the GUI shown in fig.6.4 pops up. Here the status and override can be set and the specific interlock status can be read.


Backing Valve TOF Branch

On

Override On

All conditions must be fufilled

Turbo pump speed > 80%

Pirani gauge <1E-7 bar

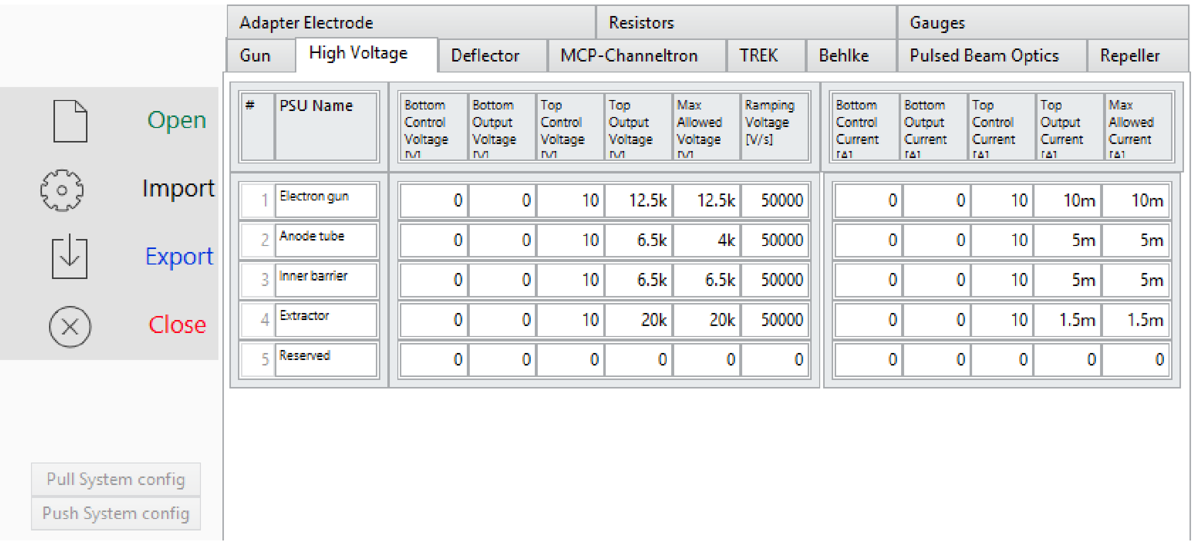
FIGURE 6.4: GUI for the valves and pumps

A package is created when the operator changes the status of a pump. The package contains the set status and information about which pump it is. This is sent to the correct cRIO were the information gets read and if it was an off command, it turns the pump off. If it was a on request and the interlock conditions are met a command is sent to the hardware manager to turn the pump on. The valve control would be identical. The read status of the vacuum system is posted on the server of the cRIO with regular intervals and read by the GUI.

6.1.8 Static PSU

Configuration

The configuration option increases flexibility by allowing any of the PSU connections to be used with any PSU with the same interface. The operator can change the name and all the parameters of a PSU without having to changing the code itself. The GUI for the configuration contains all the required properties to be set by the operator. The configuration can be imported and exported from the file on the PC and pulled and pushed from the devices. In fig.6.5 the configuration GUI for the PSUs on HV cRIO is open. The configuration window used for the PSU is also used for the gauges and the resistors for measurement.



#	PSU Name	Bottom Control Voltage [V]	Bottom Output Voltage [V]	Top Control Voltage [V]	Top Output Voltage [V]	Max Allowed Voltage [V]	Ramping Voltage [V/s]	Bottom Control Current [A]	Bottom Output Current [A]	Top Control Current [A]	Top Output Current [A]	Max Allowed Current [A]
1	Electron gun	0	0	10	12.5k	12.5k	50000	0	0	10	10m	10m
2	Anode tube	0	0	10	6.5k	4k	50000	0	0	10	5m	5m
3	Inner barrier	0	0	10	6.5k	6.5k	50000	0	0	10	5m	5m
4	Extractor	0	0	10	20k	20k	50000	0	0	10	1.5m	1.5m
5	Reserved	0	0	0	0	0	0	0	0	0	0	0

FIGURE 6.5: Hardware Configuration

On the computer application only the max allowed values are used to stop it from requesting levels the PSU should not go to. The GUI in the computer application is not necessarily the only one that will communicate with the hardware, so the maximum values are also checked locally on the controller. The control and output values are put through this function:

$$Factor = \frac{Output_{max} - Output_{min}}{Control_{max} - Control_{min}} \tag{6.1}$$

$$Offset = \frac{Output_{min}}{Factor} - Control_{min} \tag{6.2}$$

The factor is used to scale between the control level and the output level.

Functions

Status:
When the status is set by the operator it goes to the FPGA were the conditions for set can be seen in fig.3.2 from the requirements. Setting the status only sets the on/off input and for the PSU to turn on the interlock or the override will have to be true too. There is no addition interface to check if the PSU is on, so for checking the status the output the status writes to is read and distributed.

Polarity:
For the bi-polar static PSU the status of the TTL is read before the voltage is written. If the polarity was different from the new value, the voltage level for that specific PSU is set to 0V when this is read to be 0V the TTL switches and the sets the request value to all PSUs.

Maximum Output Level:
The maximum level is checked in the hardware protocol. If the maximum value has been exceeded, the last value for the specific PSU is used instead and a error message is sent to the GUI.

Ramping:
The ramping level set in configuration decides the maximum rate of change for the voltage for the PSU. If the ramping level is set to 0, the requested voltage level will immediately be set. If it is not 0, then the configured values in V/S is divide by 10 to get the the ramping increment value. Every 100ms the value of the PSU is changed that amount towards the set level, until an increase of a ramping increment would exceed the requested voltage. When this happens the requested voltage is set.

Scaling:
Right before the the PSU current or voltages is written to the FPGA the hardware protocol divides the value with the factor and the offset is subtracted from, see eq.6.3 . When the level is read the offset is added to the value and then multiplied with the factor, see eq.6.4. The scaling happens this far down in the application so that most of the application only handle the output values, including the operator. The configuration file is opened in the hardware manager and given to the hardware protocol.

$$Value_{Control} = \frac{Value_{Output}}{Factor} - Offset \tag{6.3}$$

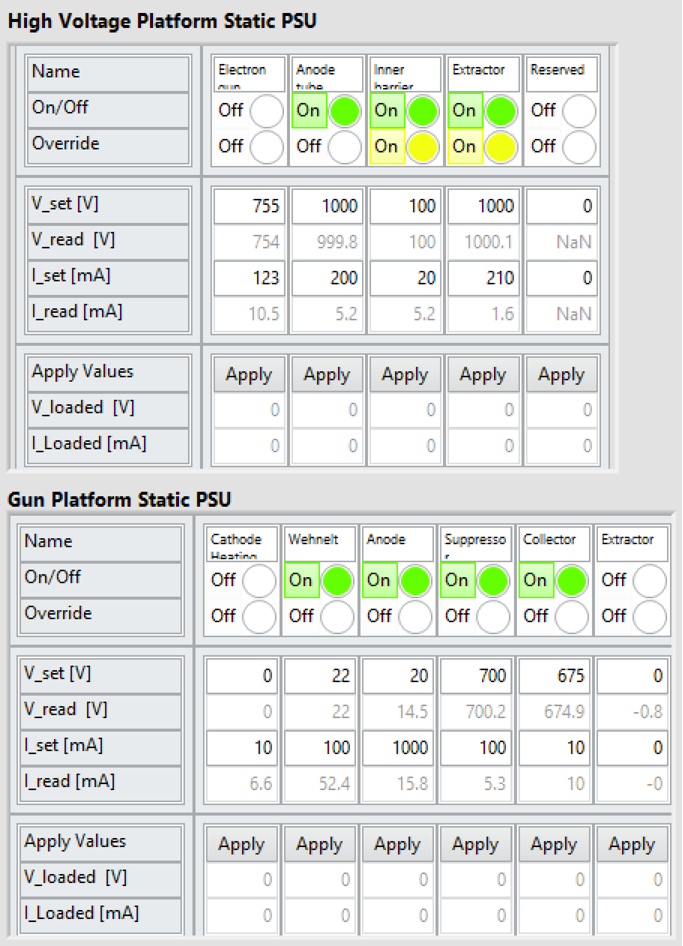
$$Value_{Output} = (Value_{Control} + Offset) * Factor \tag{6.4}$$

Interlocks

The interlock is done on the FPGA values. When the operator sets the on/off status it is sent to the correct variable and it is kept there, but as shown in fig.3.2 in the interlock requirements for the PSU, it will also need an positive input from the interlock it is coupled with or an override signal from the operator.

Controlling the PSU

In fig.6.6 the control for the static PSUs on the high voltage and gun platform can be seen.



High Voltage Platform Static PSU

Name	Electron gun	Anode tube	Inner barrier	Extractor	Reserved
On/Off	Off ○	On ●	On ●	On ●	Off ○
Override	Off ○	Off ○	On ●	On ●	Off ○
V_set [V]	755	1000	100	1000	0
V_read [V]	754	999.8	100	1000.1	NaN
I_set [mA]	123	200	20	210	0
I_read [mA]	10.5	5.2	5.2	1.6	NaN
Apply Values	Apply	Apply	Apply	Apply	Apply
V_loaded [V]	0	0	0	0	0
I_Loaded [mA]	0	0	0	0	0

Gun Platform Static PSU

Name	Cathode Heating	Wehnelt	Anode	Suppressor	Collector	Extractor
On/Off	Off ○	On ●	On ●	On ●	On ●	Off ○
Override	Off ○	Off ○	Off ○	Off ○	Off ○	Off ○
V_set [V]	0	22	20	700	675	0
V_read [V]	0	22	14.5	700.2	674.9	-0.8
I_set [mA]	10	100	1000	100	10	0
I_read [mA]	6.6	52.4	15.8	5.3	10	-0
Apply Values	Apply	Apply	Apply	Apply	Apply	Apply
V_loaded [V]	0	0	0	0	0	0
I_Loaded [mA]	0	0	0	0	0	0

FIGURE 6.6: Static PSU GUI

From this interface the operator sets the values and the status of each PSU and it indicates the current status and levels for the PSUs. When the operator changes a value all the values for that group of PSU is sent to the correct cRIO and ends up in the hardware protocol. The hardware protocol checks if the value is within the maximum range and then scales it to the correct control voltage before being writing it to the FPGA variable. The FPGA sets the value to output.

When sending up it is a similar process. The hardware protocol read the FPGA variable, scales the values and the hardware manager packages and sends it to the GUI. When the GUI is opened for the first time it files all the set values from the last set operation. This data is stored on the server so it does not matter if the PC is changed or restarted.

6.1.9 Measurement

The PXI does all the measurements for the beam intensity and the time-of-flight, but the cRIO sets the status of the pistons the FC are connected too. This pistons move the FC in front of the beam, interrupting it from going further. The status of the piston is continually updated and displayed on the GUI. When the operator presses the button to set status of the piston a packages is sent to the correct cRIO and it is done.

6.2 PXI

The PXI Controllers are in charge of everything that is time-critical. This includes the pulsed PSU and measurements.

6.2.1 The Controlling Element of the PXI

The controller of a PXI is like a PC specialized for acquisition and control of hardware. The PXIs for the TwinEBIS test bench uses a OS for the PXI called Phar Lap which makes it a RT controller. This is what controls everything and were the application is deployed. There are two types of PXI cards used on the TwinEBIS test bench: those with FPGA and those without FPGA. The ones without FPGA is controlled directly from the RT and have configurable aspects like voltage range, sample time etc. On the FPGA the these parameters has to be manually coded.

6.2.2 Architecture

- **Hardware protocol:** abstracts away how to control a card to a common class so that setting and getting voltage would be identical from the outside irregardless of the specific card.
- **Hardware manager:** communicates with hardware protocol. Hardware manager does not know how to control the cards, but it knows when, why and what it should do.
- **Communication manager:** enables communication to other devices. Explain in the last chapter.
- **Root:** binds everything together. It starts everything, monitors the system and chooses where packages from the communication manager should go. It contains the information on what each individual PXI can do

In fig.6.7 these individual elements are separated and who they can directly communicates is marked with lines. Each card runs in parallel and only communicates with the hardware manager. There is a root for each of the PXI, each containing individual information for operation of the PXI. They should not run at the same time.

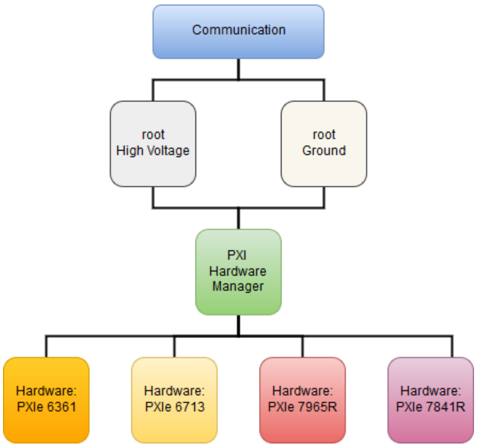


FIGURE 6.7: PXI architecture

6.2.3 Hardware Protocol

Purpose

The hardware protocol compartmentalizes all the PXI cards used into a common class. The specific operations of each card is abstracted away and generalised into common methods that exist in the parent making interaction with any of the cards identical. The protocol knows the sampling rate and other values for the individual cards.

Functionality

The parent has a methods for all the broader functionality, but they are either empty or contains code that must be used by all the card. Each card is child that override these methods and if the specific card does not have a specific functionality then calling the method causes an error that indicates this.

If a card was to be changed with a card that already existed one would only need to swap the class that got initialized. This gives the flexible that is striven for in this application. There is a parallel process for each PXI class protocol because of the precis timing required.

Challenge

Another important aspect is the synchronisation of all the actions on the cards. This means the actions cannot run as fast as possible, but instead they arm them self and wait for a trigger. When the trigger is received it read an analog waveform, write an analog waveform or write a TTL signal, and then re-arm itself as fast as possible so it is ready for the next trigger. The largest difficulty here was that the waveform and the cycle time was the same and re-arming is not instance. This meant there was not time to re-arm itself before the next trigger signal, which means it would skip a cycle. On most of the cards the re-arming was automatic and done so quickly this was not an issue, but for the analog output card in control of the TREK PSU on the HV PXI this was not the case. The re-arming needed to be done manually by polling a specific method for the card. This action took around 1ms. The solution was based on two constant of the applications. The waveform was a square wave and the last section, T_{clean}, was always there. The AO card in use kept the output at the last value given. By reducing the length of the T_{clean} part of the waveform by the time it took to re-arm the trigger synchronization was achieved.

6.2.4 Hardware Manager

Purpose

Similar to the cRIO, the hardware manager on the PXI does not know how to control the hardware.

Functionality

When the hardware manager starts the different hardware protocols it saves their communication reference in such a way that a card gets all the data they need. When a waveform for a specific card comes in it is just sent to that card, but when an update in the time of the operational cycle comes in this is sent to all the cards. This sorting and sharing data is the main task of the hardware manager while it is running.

6.2.5 Root

Purpose

On the PXI the root contains the individual information for a PXI. It initializes the communication manager and the hardware manager with the correct values and when it is running it sorts the data going in and out of the PXI.

Functionality

Which root the application starts with chooses how the application unfolds. The communication manager is started with the configuration file and name, like the cRIO. The hardware manager starts it is initialized with different methods and this is what chooses which card is used. When the root starts it also detects if it is running on a PC and then it starts simulated hardware protocols. This is a common theme in the control system as this made it possible to test in a computer rather than having to build and deploy it on a remote device for every test, as this would make it harder to find error and test new features.

When the root is running it sends out a heartbeat and checks and handles the packages in the same way as the cRIOs does. The methods it calls and the packages it looks for is different, but approach is the same.

6.2.6 Pulsed PSU

Configuration

The configuration of the pulsed PSU is identical to the static PSU configuration. Go to 6.1.8 for more information.

Status and interlocks

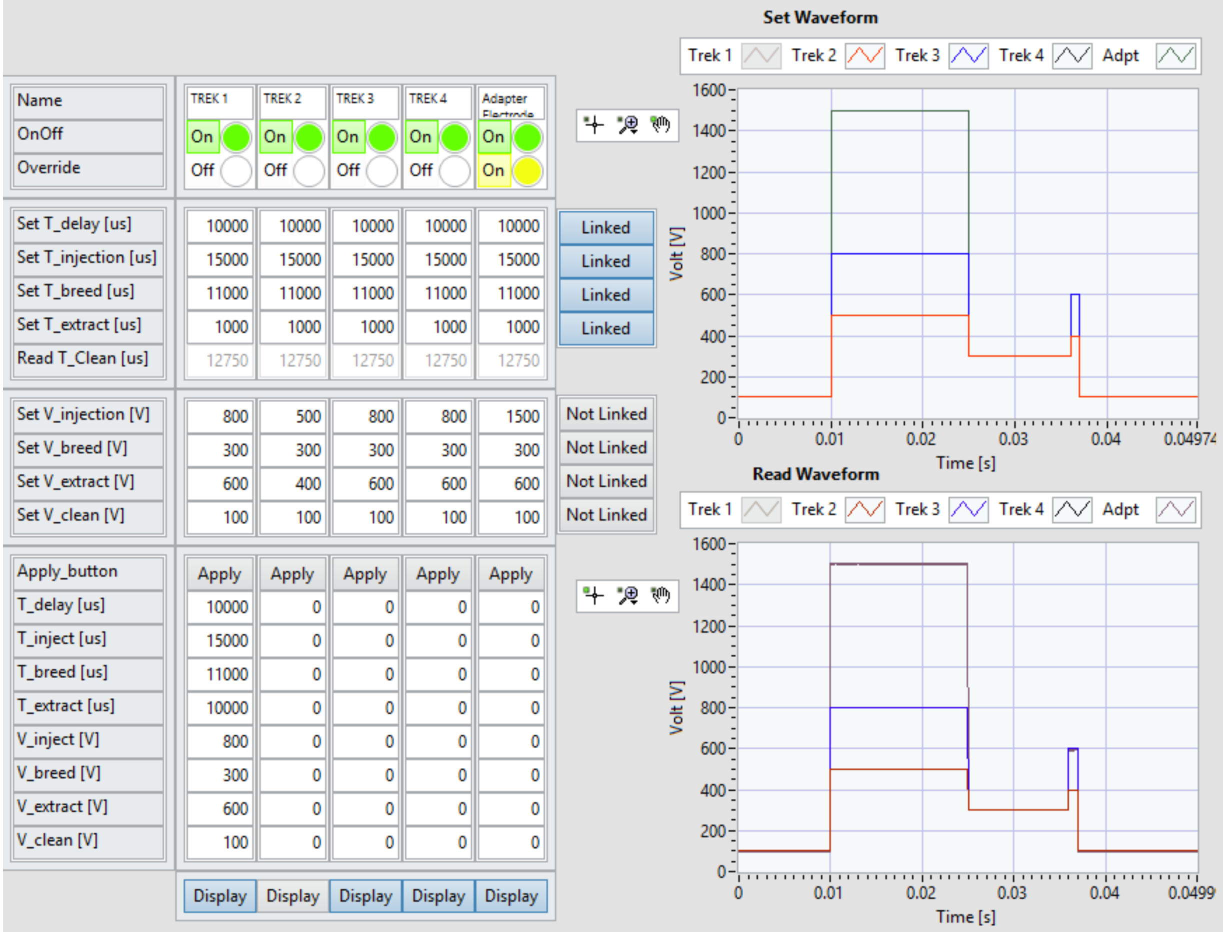
The status and interlock is controlled by a cRIO and in the exact way described in the cRIO section 6.1.8.

Scaling and Maximum values

Before the waveform is set to be outputted the values gets checked and scaled. Each element in the waveform is checked and if any of the elements in the waveform is outside the configured range the whole waveform is rejected. The factor and offset used to scale the voltages also work as on the cRIO, but instead of doing it to single element like on the cRIO the the offset and factor needs to be applied to every element in a waveform for the pulsed PSU that are controlled with a waveform.

Controlling the PSUs

As explained in the requirement sections the waveform is created from sets of voltages and time intervals. These are similar but not identical on all of the pulsed PSU. In fig.6.8 the control for the TREK PSUs can be seen. The control for the deflectors and the behlke is similar but the TREK has more sets voltage and time intervals.



Name	TREK 1	TREK 2	TREK 3	TREK 4	Adapter Electrode	
OnOff	On ●	On ●	On ●	On ●	On ●	
Override	Off ○	Off ○	Off ○	Off ○	On ●	
Set T_delay [us]	10000	10000	10000	10000	10000	Linked
Set T_injection [us]	15000	15000	15000	15000	15000	Linked
Set T_breed [us]	11000	11000	11000	11000	11000	Linked
Set T_extract [us]	1000	1000	1000	1000	1000	Linked
Read T_Clean [us]	12750	12750	12750	12750	12750	
Set V_injection [V]	800	500	800	800	1500	Not Linked
Set V_breed [V]	300	300	300	300	300	Not Linked
Set V_extract [V]	600	400	600	600	600	Not Linked
Set V_clean [V]	100	100	100	100	100	Not Linked
Apply_button	Apply	Apply	Apply	Apply	Apply	
T_delay [us]	10000	0	0	0	0	
T_inject [us]	15000	0	0	0	0	
T_breed [us]	11000	0	0	0	0	
T_extract [us]	10000	0	0	0	0	
V_inject [V]	800	0	0	0	0	
V_breed [V]	300	0	0	0	0	
V_extract [V]	600	0	0	0	0	
V_clean [V]	100	0	0	0	0	
	Display	Display	Display	Display	Display	

FIGURE 6.8: Pulsed PSU GUI

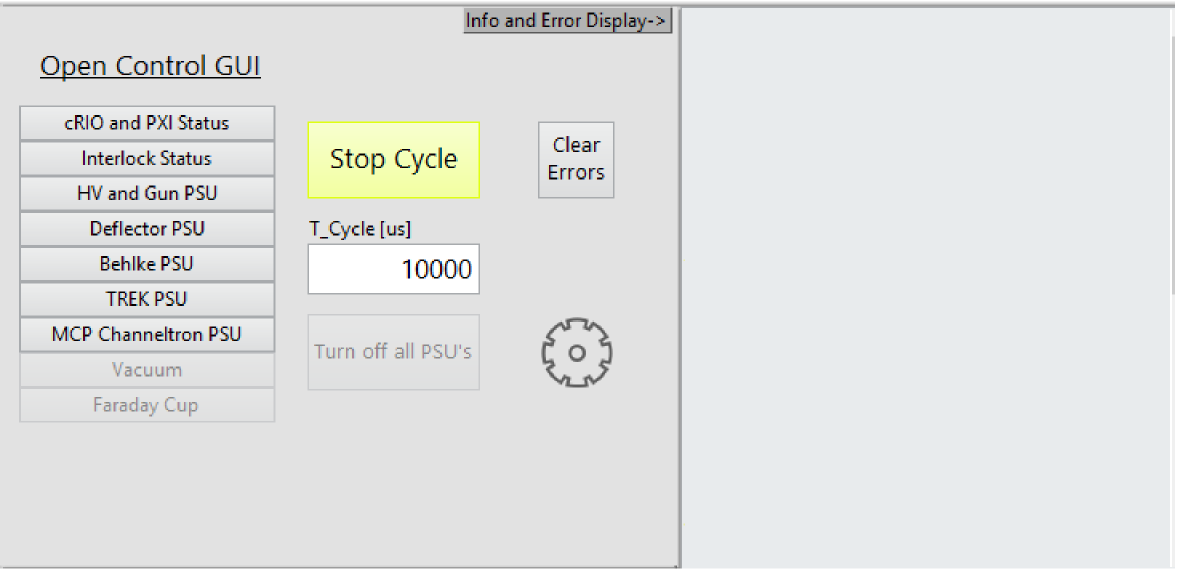
The operator sets the values for each of the PSU and the waveform gets created, sent to the PXI and displayed on the top graph. The bottom graph is the read waveform. This is to see that what is actually sent out is the same as what the PSU sends out.

When the status is changed a package is created for all the values and sent to a cRIO. When any of the times or voltages are changed all values are propagated, but how it is package depends on if it is a switching or waveform controlled PSU.

For the switching PSU the time and voltage is separated and package individually. The time is sent to the PXI for the TTL and the voltage is sent to a cRIO for the static PSU. The values are also used to create simulated waveform for the set waveform graph. The waveform controlled PSU the time and voltage is sent to a function which creates a waveform from it with the correct amount of samples for the PSU it is going to. This waveform is sent to the GUI to be displayed and the PXI to be set. The TTL and waveform ends up in the hardware protocol were their values a check to corresponds to the configuration and the cycle time.

6.2.7 Measurement

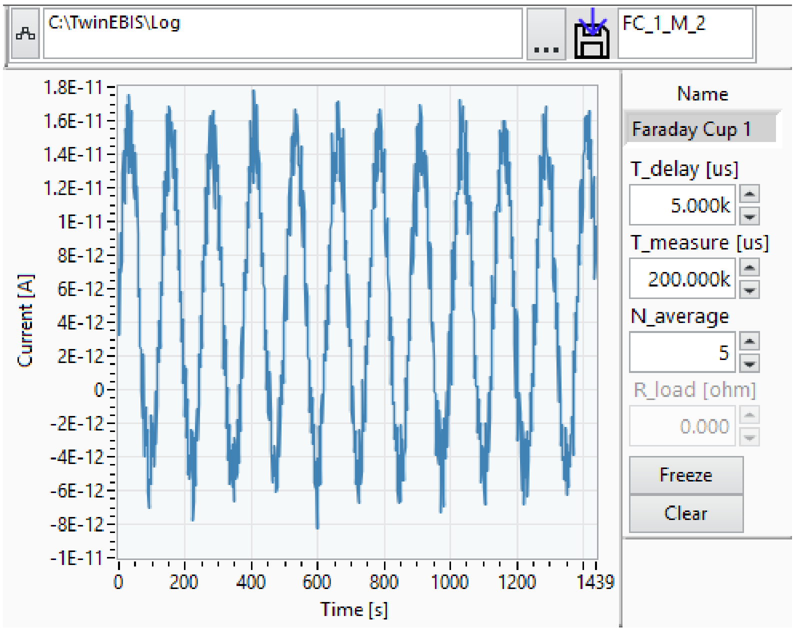
The PXI acquisition continuous as long the operational cycle is running. The time and status is controlled from the front page of the GUI application seen in fig.6.9. A change here is packaged and sent to the PXIs.



T_Cycle [us]: 10000

FIGURE 6.9: Front Panel GUI for the TwinEBIS test bench

Fig.6.10 is an interface for the FCs. They are identical for all the FCs to keep it simple for the operator. Here the width of the measurement is set and how many samples would be averaged for each point. There is the possibility to freeze, save and clear the graph.


C:\TwinEBIS\Log

FC_1_M_2

Name: Faraday Cup 1

T_delay [us]: 5.000k

T_measure [us]: 200.000k

N_average: 5

R_load [ohm]: 0.000

FIGURE 6.10: Faraday Cup GUI

6.2.8 Synchronisation

To get all the cards on all the PXI to synchronise there needs to be something that keeps track of time and starts them at the same time. The physical connection between the PXIs are setup sending a trigger from the HV PXI to the ground PXI. Internally in every PXI there is a direct trigger to the cards. The HV PXI creates the trigger and could send it to the cards and the ground PXI at the same time, but the difference in propagation delay of the fiber trigger and the inner workings of the PXI would make them not start at the same time. Appendix A shows how the trigger signal is propagated through the system to synchronize events. It also indicates which card is part of which PXI and physically were the trigger signal travels. This cycle is what controls the timing of all the measurement and pulsed PSU.

Chapter 7

Results

7.1 Requirements

Identifying the requirements for the TwinEBIS test bench and using them to formulate the requirements are a central point in this thesis. It made it possible to work on the details of the development without losing the big picture. Creating the requirement documentation that was consistent with itself and the other documentation was an important foundation for the rest of the development.

7.2 Hardware and Software choices

Using LabVIEW was useful in the respect that creating all the code within this one environment reduced the time it took to test new feature and enabled the reuse of the functions and classes on all devices.

After the system was done a PSU with only voltage control was changed with one with current and voltage control. Having spare connection for this made the change quick and easy. This meant only having to move a label on the patch panel, changing a line in the documentation and less than 10 minutes of work in the software.

The ethernet infrastructure with the fibers were plug and play. It worked as expected. The network was tested and it worked to the maximum of its capabilities, but these maximum capabilities are not utilized with the system running now. This will allow more features to be added to the system without having to upgrade it.

7.2.1 Communication Framework

The communication framework was developed before the rest of the applications was planned in detail. This required it to have the flexibility to adapt to any data type or protocol that was going to be used and be functional on any of the controllers and computer. The communication framework did this. After the communication framework was created and the bugs were tested out, it was flawless to implement on all the devices. If there was a problem when sending it from A to B the problem was always outside of the communication framework. It was very useful to have a large part of the application work consistently as it made debugging the rest of the application quicker and easier.

When the communication framework was finished it was apparent that it was flexible enough to be used in other applications. If another application had similar communication needs it could save time by reusing this framework.

7.3 Control System

Making a application for four cRIOs and one application for two PXIs worked well. The initial idea to have six applications would have been a lot more time consuming. Maintaining two applications saved time and adding new PXIs or cRIOs at a later time would not have required the development of a completely new application, but instead a small addition to the existing application. With the help of the communication framework and how the controllers were set up, each device worked as independently as possible. The division on cRIO and PXI into smaller parts like hardware manager, hardware protocol, root etc. made it easy to make the change the physicist came with under and after the application was done. The compartmentalizing meant that all changes only needed to be edited locally, which saved time.

Controlling the PSU went as intended. Each PSU controlled the correct PSU in the way it should. The configurations gave the operator also the flexibility to change PSUs or change the settings. The scaling and the safety mechanism were tested before PSUs were added and they worked nominally and continued to do so after the PSU were attached.

The synchronization was a critical aspect of the application. Every task tied to the cycle started exactly on the trigger without any noticeable jitter. This made the measurement timing correct and the operators could do the experiments they planned to do.

7.4 Additional Results from the Focus on Flexibility

7.4.1 Using the Control System for more than Cancer Treatment Research

The main goal for the physicist was to have a control system for the TwinEBIS test bench for the cancer treatment research. After the completion the operators and the physicist said that they also wanted to use this for other experiments. This was not a requirement, but it would be practical as the TwinEBIS can ionize more than carbon. The flexibility added to the system made it possible to utilize the same control system for the TwinEBIS test bench as a general control system for the TwinEBIS, without any modifications.

7.4.2 Non-LabVIEW Interface

The communication framework was made in such a way that it does not need to use LabVIEW with it. As mentioned all the devices are also independent from the computer. These two features made it possible for one of the operators to make interface into the control system in other programming languages. This was not part of the requirement, but was a result of the focus on flexibility and self-reliance.

7.5 Conclusion

The development of the control system for the CERN TwinEBIS test bench described in this thesis comprised of the assessment of requirements, the selection and purchase of hardware, the creation of firmware, control software and graphical user interfaces and concluded with the successful commissioning in 2019. The implementation has proven to be fulfilled and exceed the original requirements presented by the physicist and operators of the experiment installation. Adaptations to the graphical user interface and the underlying control algorithms could be implemented with a relative ease due to both the close and frequent collaboration with the end users of the product, as well as the rapid prototyping nature and streamlined deployment capabilities of LabVIEW, which was chosen as the development environment. Focusing on flexibility and modularity from the onset of this engineering project made it possible to adapt to the inevitable changes encountered during the implementation process and to create an easily extendable framework that is future-proof to cope with future planning challenges. Physicists, operators and the LabVIEW software development team at CERN have been involved and satisfied with all phases of the realization of this project and thus made the creation of the control system for the TwinEBIS test bench a success.

List of Figures

Bibliography

[1] ajvs. *PFEIFFER TMU 521*. URL: https://www.ajvs.com/new/product_info.php?products_id=6121. (accessed: 01.06.2019).

[2] CABOTO collaboration and TERA collaboration. *TwinEBIS Full Setup*.

[3] Distrelec. *EKI-2741SX - Industrial Ethernet Fiber Converter, Advantech*. URL: https://www.distrelec.ch/en/industrial-ethernet-fiber-converter-advantech-eki-2741sx/p/12567018?q=ethernet+fiber&page=2&origPos=2&origPageSize=25&simi=99.87. (accessed: 01.06.2019).

[4] Heidelberg University Hospital. *Proton Therapy and Carbon Ion Therapy*. URL: https://www.heidelberg-university-hospital.com/diseases-treatments/tumor-diseases/proton-therapy-and-carbon-ion-therapy/. (accessed: 01.06.2019).

[5] Meinberg. *TTL to Fiber, Fiber to TTL*. URL: https://www.meinbergglobal.com/download/docs/shortinfo/english/info_fo-converter.pdf. (accessed: 01.06.2019).

[6] Hannes Pahl. *EBIS Charge Abundance*. URL: http://ebis.web.cern.ch/ebisim/. (accessed: 01.06.2019).

[7] Scripps Health in San Diego. *Bragg Peak*. Picture http://www.pictureicon.com/images/bragg-peak-proton-therapy-scripps-health.jpg 01.06.2019.

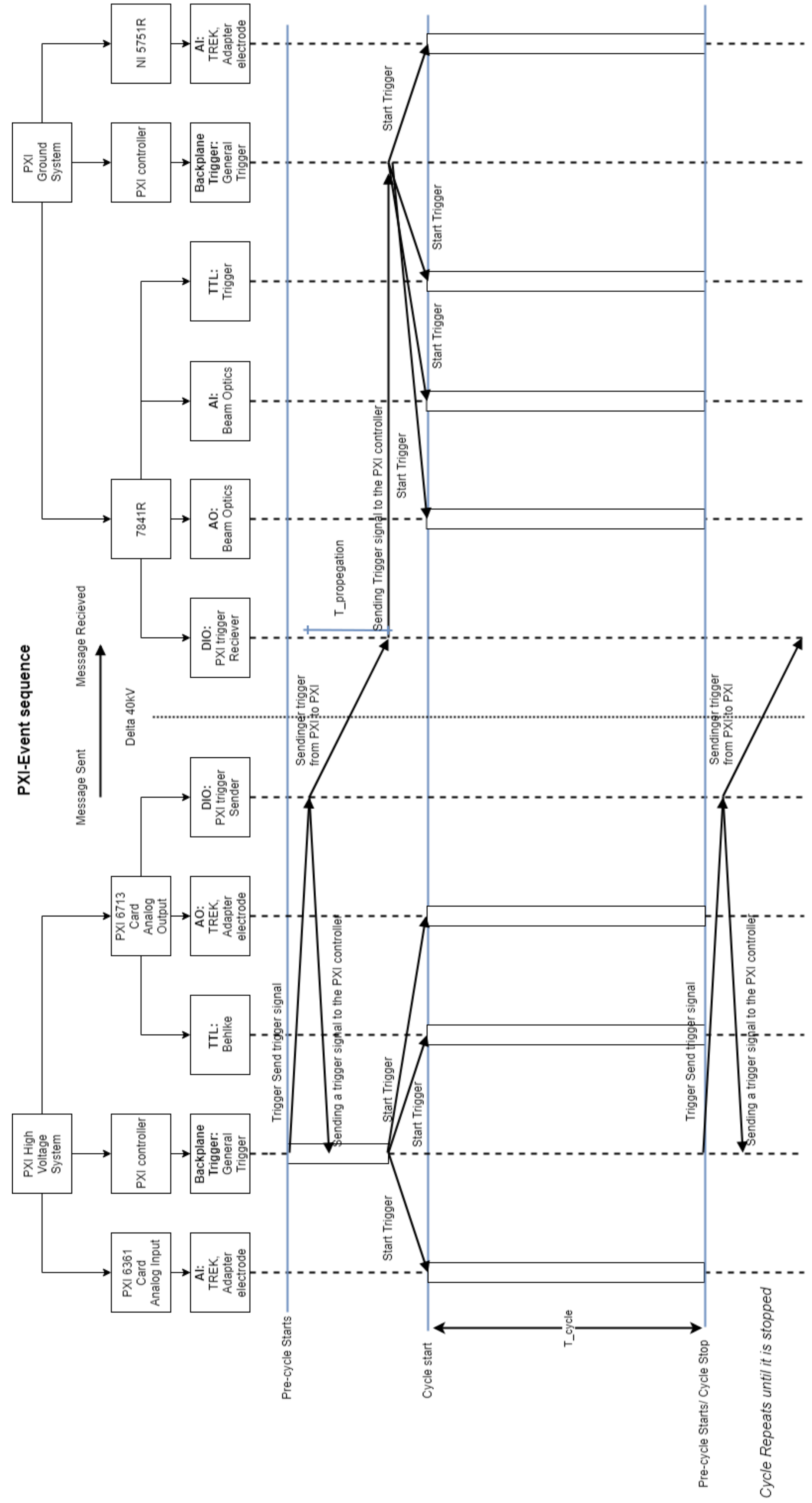
[8] PFEIFFER Vacuum. *Operating Instructions: TPG 300 Plug-Ins*. URL: http://lmu.web.psi.ch/docu/manuals/bulk_manuals/Pfeiffer/TPG_300_plugin.pdf. (accessed: 01.06.2019).

[9] Fredrik Wernander. *TwinEBIS Graphical Rendition*.

[10] wikipedia. *TTL interfacing considerations*. URL: https://www.heidelberg-university-hospital.com/diseases-treatments/tumor-diseases/proton-therapy-and-carbon-ion-therapy/. (accessed: 01.06.2019).

Appendix A

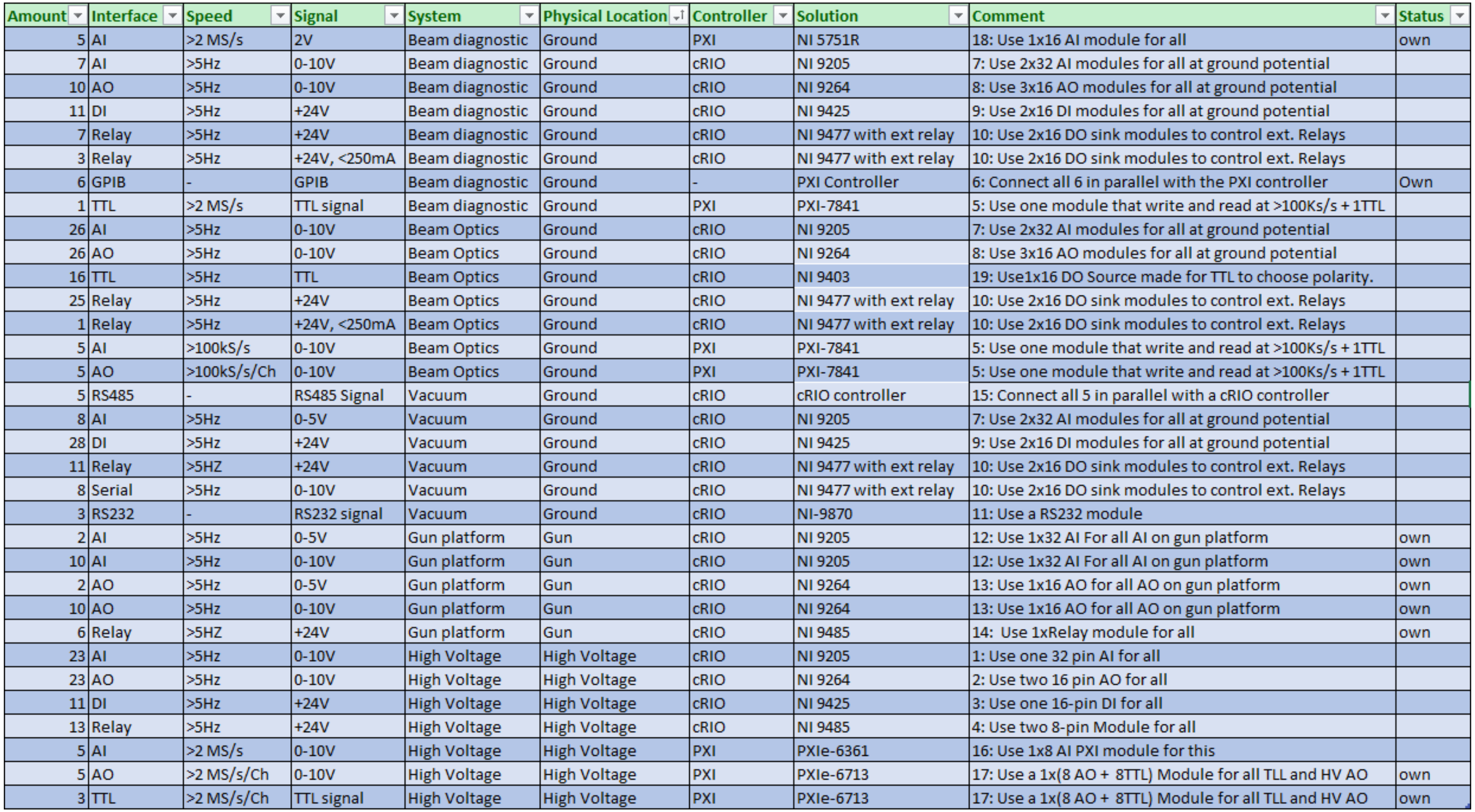
PXI Cycle Sequence


PXI-Event sequence
Message Sent
Message Recieved
Delta 40kV
PXI High Voltage System
PXI Ground System
PXI 6361 Card Analog Input
PXI controller
PXI 6713 Card Analog Output
7841R
PXI controller
NI 5751R
AI: TREK, Adapter electrode
Backplane Trigger: General Trigger
TTL: Behlke
AO: TREK, Adapter electrode
DIO: PXI trigger Sender
DIO: PXI trigger Reciever
AO: Beam Optics
AI: Beam Optics
TTL: Trigger
Backplane Trigger: General Trigger
AI: TREK, Adapter electrode
Trigger Send trigger signal
Sending a trigger signal to the PXI controller
Start Trigger
Start Trigger
Sendinger trigger from PXI to PXI
T_propegation
Sending Trigger signal to the PXI controller
Start Trigger
Start Trigger
Start Trigger
Start Trigger
Trigger Send trigger signal
Sending a trigger signal to the PXI controller
Sendinger trigger from PXI to PXI
Pre-cycle Starts
Cycle start
T_cycle
Pre-cycle Starts/ Cycle Stop
Cycle Repeats until it is stopped

Appendix B

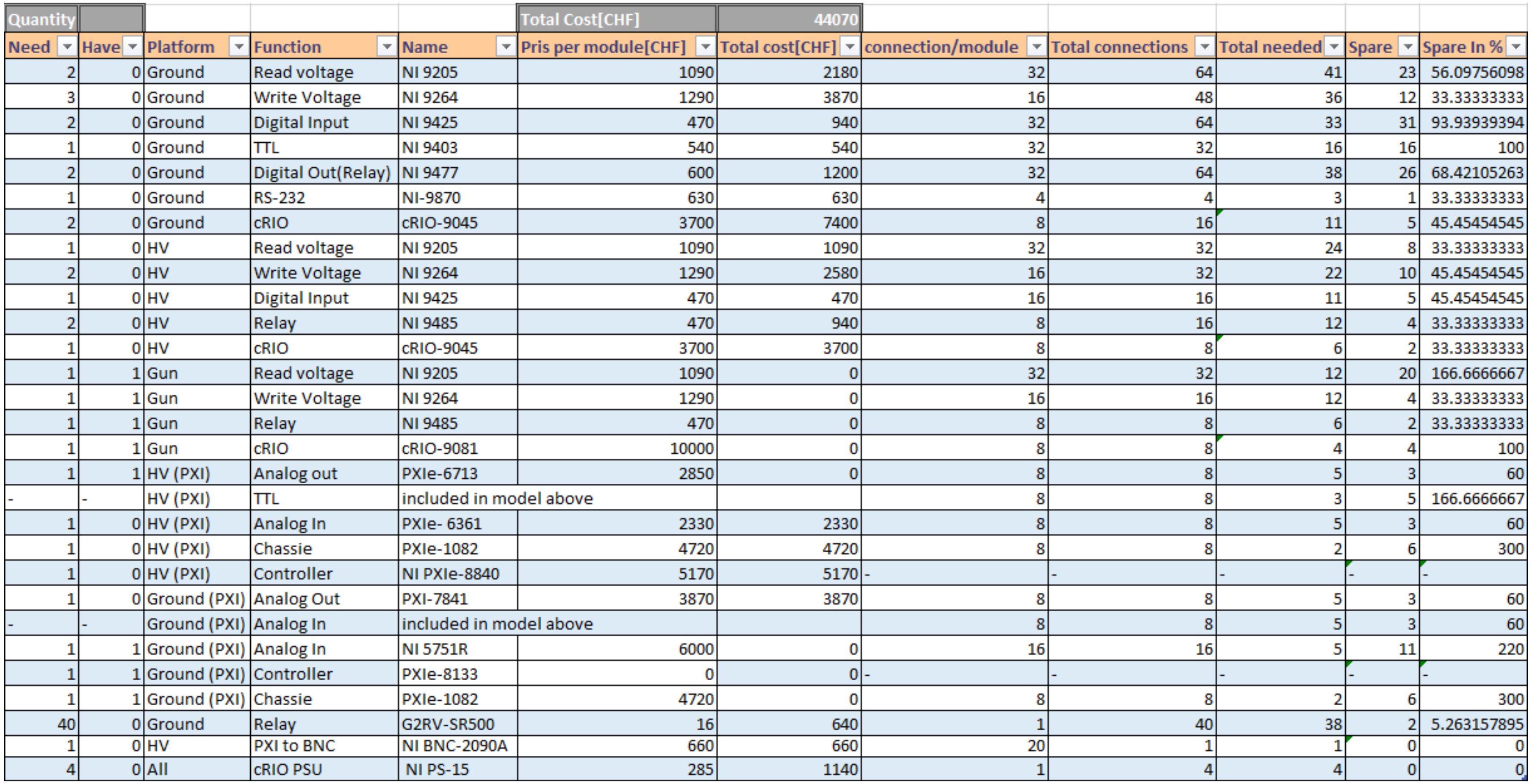
Requirement and Order Table

TABLE B.1: Table of solution to requirements



Amount	Interface	Speed	Signal	System	Physical Location	Controller	Solution	Comment	Status
5	AI	>2 MS/s	2V	Beam diagnostic	Ground	PXI	NI 5751R	18: Use 1x16 AI module for all	own
7	AI	>5Hz	0-10V	Beam diagnostic	Ground	cRIO	NI 9205	7: Use 2x32 AI modules for all at ground potential	
10	AO	>5Hz	0-10V	Beam diagnostic	Ground	cRIO	NI 9264	8: Use 3x16 AO modules for all at ground potential	
11	DI	>5Hz	+24V	Beam diagnostic	Ground	cRIO	NI 9425	9: Use 2x16 DI modules for all at ground potential	
7	Relay	>5Hz	+24V	Beam diagnostic	Ground	cRIO	NI 9477 with ext relay	10: Use 2x16 DO sink modules to control ext. Relays	
3	Relay	>5Hz	+24V, <250mA	Beam diagnostic	Ground	cRIO	NI 9477 with ext relay	10: Use 2x16 DO sink modules to control ext. Relays	
6	GPIB	-	GPIB	Beam diagnostic	Ground	-	PXI Controller	6: Connect all 6 in parallel with the PXI controller	Own
1	TTL	>2 MS/s	TTL signal	Beam diagnostic	Ground	PXI	PXI-7841	5: Use one module that write and read at >100Ks/s + 1TTL	
26	AI	>5Hz	0-10V	Beam Optics	Ground	cRIO	NI 9205	7: Use 2x32 AI modules for all at ground potential	
26	AO	>5Hz	0-10V	Beam Optics	Ground	cRIO	NI 9264	8: Use 3x16 AO modules for all at ground potential	
16	TTL	>5Hz	TTL	Beam Optics	Ground	cRIO	NI 9403	19: Use1x16 DO Source made for TTL to choose polarity.	
25	Relay	>5Hz	+24V	Beam Optics	Ground	cRIO	NI 9477 with ext relay	10: Use 2x16 DO sink modules to control ext. Relays	
1	Relay	>5Hz	+24V, <250mA	Beam Optics	Ground	cRIO	NI 9477 with ext relay	10: Use 2x16 DO sink modules to control ext. Relays	
5	AI	>100kS/s	0-10V	Beam Optics	Ground	PXI	PXI-7841	5: Use one module that write and read at >100Ks/s + 1TTL	
5	AO	>100kS/s/Ch	0-10V	Beam Optics	Ground	PXI	PXI-7841	5: Use one module that write and read at >100Ks/s + 1TTL	
5	RS485	-	RS485 Signal	Vacuum	Ground	cRIO	cRIO controller	15: Connect all 5 in parallel with a cRIO controller	
8	AI	>5Hz	0-5V	Vacuum	Ground	cRIO	NI 9205	7: Use 2x32 AI modules for all at ground potential	
28	DI	>5Hz	+24V	Vacuum	Ground	cRIO	NI 9425	9: Use 2x16 DI modules for all at ground potential	
11	Relay	>5HZ	+24V	Vacuum	Ground	cRIO	NI 9477 with ext relay	10: Use 2x16 DO sink modules to control ext. Relays	
8	Serial	>5Hz	0-10V	Vacuum	Ground	cRIO	NI 9477 with ext relay	10: Use 2x16 DO sink modules to control ext. Relays	
3	RS232	-	RS232 signal	Vacuum	Ground	cRIO	NI-9870	11: Use a RS232 module	
2	AI	>5Hz	0-5V	Gun platform	Gun	cRIO	NI 9205	12: Use 1x32 AI For all AI on gun platform	own
10	AI	>5Hz	0-10V	Gun platform	Gun	cRIO	NI 9205	12: Use 1x32 AI For all AI on gun platform	own
2	AO	>5Hz	0-5V	Gun platform	Gun	cRIO	NI 9264	13: Use 1x16 AO for all AO on gun platform	own
10	AO	>5Hz	0-10V	Gun platform	Gun	cRIO	NI 9264	13: Use 1x16 AO for all AO on gun platform	own
6	Relay	>5HZ	+24V	Gun platform	Gun	cRIO	NI 9485	14: Use 1xRelay module for all	own
23	AI	>5Hz	0-10V	High Voltage	High Voltage	cRIO	NI 9205	1: Use one 32 pin AI for all	
23	AO	>5Hz	0-10V	High Voltage	High Voltage	cRIO	NI 9264	2: Use two 16 pin AO for all	
11	DI	>5Hz	+24V	High Voltage	High Voltage	cRIO	NI 9425	3: Use one 16-pin DI for all	
13	Relay	>5Hz	+24V	High Voltage	High Voltage	cRIO	NI 9485	4: Use two 8-pin Module for all	
5	AI	>2 MS/s	0-10V	High Voltage	High Voltage	PXI	PXIe-6361	16: Use 1x8 AI PXI module for this	
5	AO	>2 MS/s/Ch	0-10V	High Voltage	High Voltage	PXI	PXIe-6713	17: Use a 1x(8 AO + 8TTL) Module for all TLL and HV AO	own
3	TTL	>2 MS/s/Ch	TTL signal	High Voltage	High Voltage	PXI	PXIe-6713	17: Use a 1x(8 AO + 8TTL) Module for all TLL and HV AO	own

TABLE B.2: Table of orders



Quantity					Total Cost[CHF]	44070					
Need	Have	Platform	Function	Name	Pris per module[CHF]	Total cost[CHF]	connection/module	Total connections	Total needed	Spare	Spare In %
2	0	Ground	Read voltage	NI 9205	1090	2180	32	64	41	23	56.09756098
3	0	Ground	Write Voltage	NI 9264	1290	3870	16	48	36	12	33.33333333
2	0	Ground	Digital Input	NI 9425	470	940	32	64	33	31	93.93939394
1	0	Ground	TTL	NI 9403	540	540	32	32	16	16	100
2	0	Ground	Digital Out(Relay)	NI 9477	600	1200	32	64	38	26	68.42105263
1	0	Ground	RS-232	NI-9870	630	630	4	4	3	1	33.33333333
2	0	Ground	cRIO	cRIO-9045	3700	7400	8	16	11	5	45.45454545
1	0	HV	Read voltage	NI 9205	1090	1090	32	32	24	8	33.33333333
2	0	HV	Write Voltage	NI 9264	1290	2580	16	32	22	10	45.45454545
1	0	HV	Digital Input	NI 9425	470	470	16	16	11	5	45.45454545
2	0	HV	Relay	NI 9485	470	940	8	16	12	4	33.33333333
1	0	HV	cRIO	cRIO-9045	3700	3700	8	8	6	2	33.33333333
1	1	Gun	Read voltage	NI 9205	1090	0	32	32	12	20	166.6666667
1	1	Gun	Write Voltage	NI 9264	1290	0	16	16	12	4	33.33333333
1	1	Gun	Relay	NI 9485	470	0	8	8	6	2	33.33333333
1	1	Gun	cRIO	cRIO-9081	10000	0	8	8	4	4	100
1	1	HV (PXI)	Analog out	PXIe-6713	2850	0	8	8	5	3	60
-	-	HV (PXI)	TTL	included in model above			8	8	3	5	166.6666667
1	0	HV (PXI)	Analog In	PXIe- 6361	2330	2330	8	8	5	3	60
1	0	HV (PXI)	Chassie	PXIe-1082	4720	4720	8	8	2	6	300
1	0	HV (PXI)	Controller	NI PXIe-8840	5170	5170	-	-	-	-	-
1	0	Ground (PXI)	Analog Out	PXI-7841	3870	3870	8	8	5	3	60
-	-	Ground (PXI)	Analog In	included in model above			8	8	5	3	60
1	1	Ground (PXI)	Analog In	NI 5751R	6000	0	16	16	5	11	220
1	1	Ground (PXI)	Controller	PXIe-8133	0	0	-	-	-	-	-
1	1	Ground (PXI)	Chassie	PXIe-1082	4720	0	8	8	2	6	300
40	0	Ground	Relay	G2RV-SR500	16	640	1	40	38	2	5.263157895
1	0	HV	PXI to BNC	NI BNC-2090A	660	660	20	1	1	0	0
4	0	All	cRIO PSU	NI PS-15	285	1140	1	4	4	0	0

Appendix C

Vacuum Documentation

1. Software shunts to override interlock conditions; acts on the device being interlocked and not on the interlock
2. If there has been a power cut, keep all valves closed and pumps off. Do not restart / open themselves without manual intervention.

For each branch (generic for EBIS, TOF and Ion source branches)

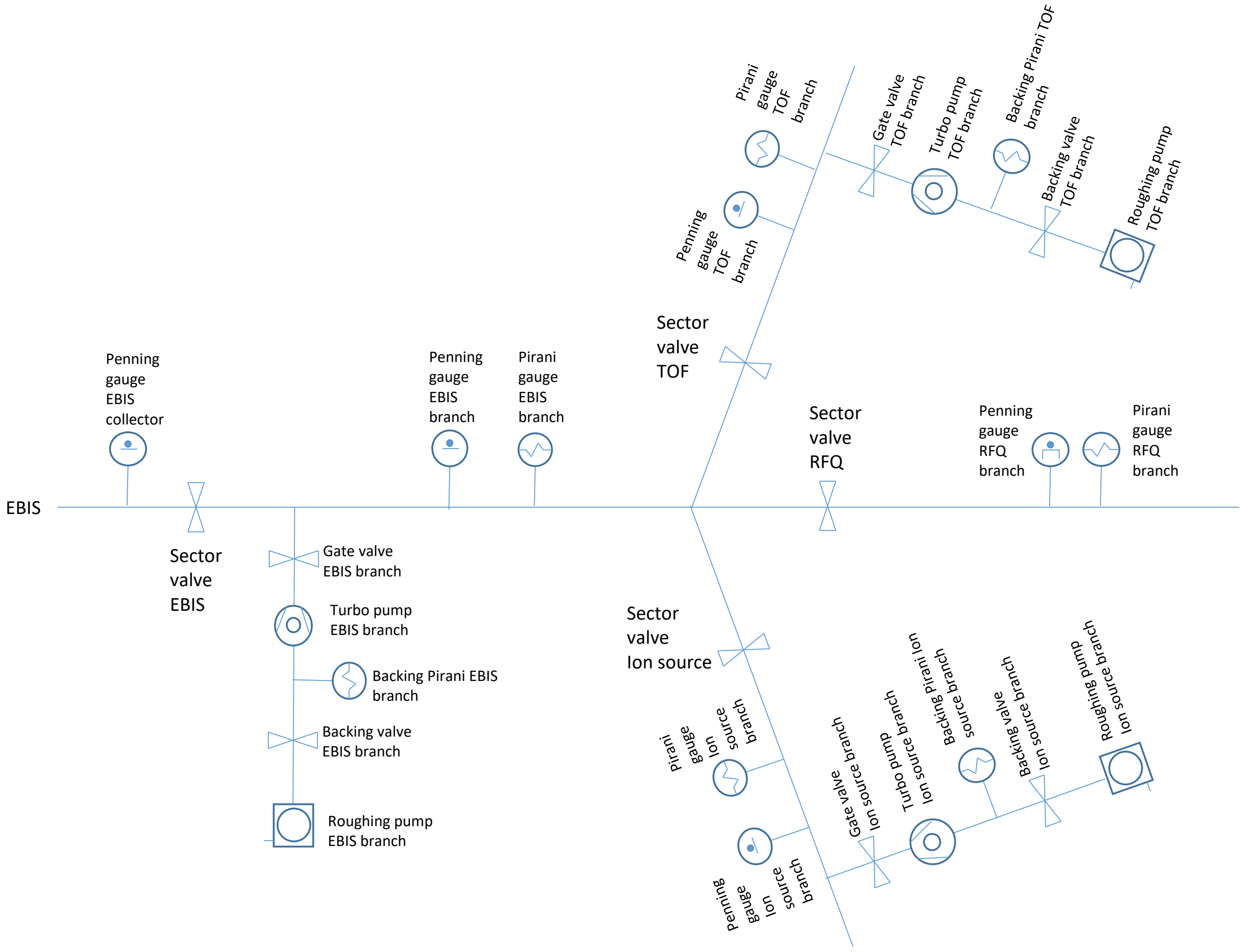
- Gate valve
  Open if 'Command open' & Turbo pump speed >80% & Pirani gauge <1E-4 mbar
  or
  'Command open' & Gate valve shunted
  Otherwise closed

- Backing valve
  Open if 'Command open' & Roughing pump running
  or
  'Command open' & Backing valve shunted
  Otherwise closed

- Turbo pump
  On if 'Command on' & Backing Pirani <1 mbar
  or
  'Command on' & Turbo pump shunted

- Roughing (backing) pump
  On if 'Command on'

- Sector valve
  Open if 'Command open' & Relay from Penning gauge upstream sector valve closed & Relay from Penning gauge downstream sector valve closed
  or
  'Command open' & Sector valve shunted
  Otherwise closed


EBIS
Penning gauge EBIS collector
Sector valve EBIS
Gate valve EBIS branch
Turbo pump EBIS branch
Backing Pirani EBIS branch
Backing valve EBIS branch
Roughing pump EBIS branch
Penning gauge EBIS branch
Pirani gauge EBIS branch
Sector valve TOF
Pirani gauge TOF branch
Penning gauge TOF branch
Gate valve TOF branch
Turbo pump TOF branch
Backing Pirani TOF branch
Backing valve TOF branch
Roughing pump TOF branch
Sector valve RFQ
Penning gauge RFQ branch
Pirani gauge RFQ branch
Sector valve Ion source
Pirani gauge Ion source branch
Penning gauge Ion source branch
Gate valve Ion source branch
Turbo pump Ion source branch
Backing Pirani Ion source branch
Backing valve Ion source branch
Roughing pump Ion source branch

Appendix D

Hardware Documentation

This appendix contains the documentation written by the physicist Dr. Fredrik John Carl Wenander.

1. Gun
2. High Voltage
3. Beam Diagnostic
4. Vacuum
5. Beam Optics

Power supply - electron gun platform

	Element	Functionality	Speed	Control voltage	Connector	Interlock signal from	Physical location	GUI	Cabling	Implementation year	Comment	
1a	Cathode heating current	Write	Slow	0-5 V	Lemo 00		Gun platform	Exists	Missing	2018		PS heats up the cathode so it emits electrons. Static
	Cathode heating current	Read	Slow	0-5 V	Lemo 00		Gun platform	Exists	Missing	2018		
1b	Cathode heating voltage	Write	Slow	0-5 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Cathode heating voltage	Read	Slow	0-5 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Cathode heating	On/Off	Slow	Relay	Lemo 2	from cRIO on EBIS HV platform	Gun platform	Exists	Missing	2018	PS on when: 'On' command active and Cathode heating interlock ok (generated on 'EBIS HV platform')	Delta Elektronik SM 7020-D http://hep.ucsb.edu/p
2a	Wehnelt current	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		Wehnelt electrode shapes the emitted electron beam. Static setting.
	Wehnelt current	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
2b	Wehnelt voltage	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Wehnelt voltage	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Wehnelt	On/Off	Slow	Relay	Lemo 2	from cRIO on EBIS HV platform	Gun platform	Exists	Missing	2018	PS on when: 'On' command active and +24 V measured on 'Relay from gun Penning gauge' (generated on 'EBIS HV platform')	FuG HCE 7-125 neg https://smt.at/wp-content/upl
3a	Anode current	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		Anode electrode that extracts the electrons. Static s
	Anode current	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
3b	Anode voltage	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Anode voltage	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Anode	On/Off	Slow	Relay	Lemo 2	from cRIO on EBIS HV platform	Gun platform	Exists	Missing	2018	PS on when: 'On' command active. The machine protection is handled separately (see Sheet:'Interlocks')	FuG HCE 350-20000 pos https://smt.at/wp-content
4a	Suppressor current	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		Electrode in front of the electron collector. Static set
	Suppressor current	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
4b	Suppressor voltage	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Suppressor voltage	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Suppressor	On/Off	Slow	Relay	Lemo 2	from cRIO on EBIS HV platform	Gun platform	Exists	Missing	2018	PS on when: 'On' command active and +24 V measured on 'Relay from collector Penning gauge' (generated 'EBIS HV platform')	FuG HCE 35-6500 pos https://smt.at/wp-content/u
5a	Collector current	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		Collector for the electron beam. Static setting.
	Collector current	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
5b	Collector voltage	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Collector voltage	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Collector	On/Off	Slow	Relay	Lemo 2	from cRIO on EBIS HV platform	Gun platform	Exists	Missing	2018	PS on when: 'On' command active and +24 V measured on 'Relay from collector Penning gauge' (generated on 'EBIS HV platform')	Spellman STR 4*6 https://www.spellmanhv.com/-/
6a	Extractor current, gun platform config	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		Electrode that extracts the ions. Static setting.
	Extractor current, gun platform config	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
6b	Extractor voltage, gun platform config	Write	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		This PS can either be placed on the Gun platofrm (gun platform config.) or at EBIS HV platform (EBIS platform config.)
	Extractor voltage, gun platform config	Read	Slow	0-10 V	Lemo 00		Gun platform	Exists	Missing	2018		
	Extractor, gun platform config	On/Off	Slow	Relay	Lemo 2	from cRIO on EBIS HV platform	Gun platform	Exists	Missing	2018	PS on when: 'On' command active and +24 V measured on 'Relay from collector Penning gauge' (generated 'EBIS HV platform')	FuG HCE 35-20000 neg https://smt.at/wp-content/

General comments
The conditions (interlocks) for the power supplies are generated on the EBIS HV platform.
Cathode heating is cricial and may not be interrupted just because the cRIO has a communication problem or similar

Hardware to produce
Patch panel for Gun platform

EBIS HV platform

Element	Functionality	Speed	Control voltage		Physical location	GUI	Cabling	Interlock signal from	Impl year	Comments		
Cathode heating interlock	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing		2018	Verify Cathode heating interlock status (see Sheet:'Interlocks') by reading a +24 V probe voltage.		
Penning gauge gun	Read	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing			Read vacuum near the gun	TPG300, scem 18.40.30.535.8	
Penning gauge collector	Read	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing			Read vacuum near the electron collector	TPG300, scem 18.40.30.535.8	
Full range gauge, turbo cube pressure	Read	Slow	RS-232	D-sub	On EBIS HV platform	Missing	Missing		2018	Read common pressure behind the gun and collector turbo pumps	Would need to read this out with RS232 interface - not foreseen until now (20180202) http://www.idealvac.com/files/brochures/Pfeiffer_TPG262_Operating_Instructions.pdf	
Electron gun supply current	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing			Puts the electron gun rack with its internal power supplies on high tension.		
Electron gun supply current	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Electron gun supply voltage	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Electron gun supply voltage	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Electron gun supply	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Existing	Existing		2018	The On/Off should drive a relay in Interlock_box_1 that can close a circuit in which 240 V runs. The actual interlock is handled in the Interlock_box_1.	FuG HCE 35-12500 neg	https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Anode tube power supply current	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing			First drift tube downstream of the gun. Static setting.		
Anode tube power supply current	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Anode tube power supply voltage	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Anode tube power supply voltage	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Anode tube power supply	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Existing	Existing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	FuG HCE 35-6500 pos	https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Inner barrier supply current	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing			Drift tube that makes up the inner axial barrier of the trap. Static setting.		
Inner barrier supply current	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Inner barrier supply voltage	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Inner barrier supply voltage	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Inner barrier supply	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Existing	Existing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	FuG HCE 35-6500 pos	https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Extractor, EBIS platform config.	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing			Electrode that extracts the ions. Static setting.		
Extractor, EBIS platform config.	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Extractor, EBIS platform config.	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Extractor, EBIS platform config.	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Existing					
Extractor, EBIS platform config.	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Existing	Existing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	FuG HCE 35-20000 neg	https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Spare supply current	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Missing			Can be used to control Extractor power supply in case it is placed on EBIS HV platform		
Spare supply current	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Missing					
Spare supply voltage	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Missing					
Spare supply voltage	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Existing	Missing					
Spare supply	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Existing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	Not decided yet	
TREK 1 supply	Write voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing				TREK drift tube configuration. These four TREK supplies can be used to control the voltages for 4 drift tubes. TREK Model 601B-4 ch	
TREK 1 supply	Read voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing					
TREK 2 supply	Write voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing					
TREK 2 supply	Read voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing					
TREK 3 supply	Write voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing					
TREK 3 supply	Read voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing					
TREK 4 supply	Write voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing					
TREK 4 supply	Read voltage	Fast	0-10 V		On EBIS HV platform	Existing	Existing					
TREK 1-4	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Existing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)		

Trap supply A	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing			Trapping tube for the ions.	Single trapping tube configuration. Voltage applied during breeding. Behlke switches between Trap supply A and B. FuG HCE 35-6500 pos. https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Trap supply A	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Trap supply A	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Trap supply A	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Trap supply A	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Missing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	
Trap supply B	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing			Trapping tube for the ions.	Single trapping tube configuration. Voltage applied during extraction, cleaning and injection. Behlke switches between Trap supply A and B. FuG HCE 35-6500 pos. https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Trap supply B	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Trap supply B	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Trap supply B	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Trap supply B	On/Off	Slow	Realy	Lemo 2	On EBIS HV platform	Missing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	
Outer barrier supply A	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing			Outer axial barrier for the trapping region.	Single trapping tube configuration. Voltage applied during breeding. Behlke switches between Outer barrier supply A and B. FuG HCE 35-6500 pos. https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Outer barrier supply A	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer barrier supply A	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer barrier supply A	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer barrier supply A	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Missing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	
Outer barrier supply B	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing			Outer axial barrier for the trapping region.	Single trapping tube configuration. Voltage applied during extraction, cleaning and injection. Behlke switches between Outer barrier supply A and B. FuG HCE 35-6500 pos. https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Outer barrier supply B	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer barrier supply B	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer barrier supply B	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer barrier supply B	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Missing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	
Outer drift tube supply A	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing			Last drift tube before electron suppressor.	Single trapping tube configuration. Voltage applied during breeding. Behlke switches between Outer drift tube supply A and B. FuG HCE 35-6500 pos. https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Outer drift tube supply A	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer drift tube supply A	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer drift tube supply A	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer drift tube supply A	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Missing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	
Outer drift tube supply B	Write voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing			Last drift tube before electron suppressor.	Single trapping tube configuration. Voltage applied during extraction, cleaning and injection. Behlke switches between Outer drift tube supply A and B. FuG HCE 35-6500 pos. https://smt.at/wp-content/uploads/smt-manual-fug-hce-englisch.pdf
Outer drift tube supply B	Read voltage	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer drift tube supply B	Write current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer drift tube supply B	Read current	Slow	0-10 V	Lemo 00	On EBIS HV platform	Missing	Missing				
Outer drift tube supply B	On/Off	Slow	Relay	Lemo 2	On EBIS HV platform	Missing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and measure +24 V on 'Relay from collector Penning gauge' (fromEBIS HV platform)	
Adaptor electrode	Write voltage	Fast	0-10 V		On EBIS platform	Missing	Missing			Beam focusing lens just after the ion extractor element. Need to change focus between ion beam being injected and extracted, thus pulsed. Change settings between Injection and Extraction while the ions are charge bred, which takes some ms. Change settings from Extraction to Injection as soon as the ion extraction from the source is done; allowed time for this change is some 100 us.	Older version of TREK 20/20 C http://www.trekinc.com/products/20-20C.asp
Adaptor electrode	Read voltage	Fast	0-10 V		On EBIS platform	Missing	Missing				
Adaptor electrode	On/Off	Slow	Relay	Lemo 2	On EBIS platform	Missing	Missing	Penning gauge relay from EBIS collector	2018	PS on when: 'On' command active and +24 V measured on 'Relay from collector Penning gauge' (see Sheet:'EBIS HV platform')	
Behlke switch trap	Write	Fast	TTL signal		On EBIS HV platform	Missing	Missing		2018	Needs to drive a 50 ohm input	Behlke 60 GHTS http://www.behlke.com/pdf/ghts.pdf
Behlke switch outer barrier	Write	Fast	TTL signal		On EBIS HV platform	Missing	Missing		2018	Needs to drive a 50 ohm input	Dito
Behlke switch outer drift tube	Write	Fast	TTL signal		On EBIS HV platform	Missing	Missing		2018	Needs to drive a 50 ohm input	Dito

Water gun	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Checks if water cooling for the gun is active
Water collector	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Dito
Water bore	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Dito
Water turbo	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Dito
Relay from collector Penning gauge	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Check if the pressure at the collector is good
Relay from gun Penning gauge	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Dito
Relay from gun Pirani gauge	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Dito
Relay from Gun platform doors	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Check if Door 1 at Gun platform is closed
Relay from anode platform cage	DI	Slow	24 V	D-sub	On EBIS HV platform	Missing	Missing	2018	Need a +24 V PS to produce a probe signal	Check if anode cage is closed (relay closed)

General comments

Need to read in the interlock signals (vacuum and water) on EBIS HV
- for the On/Off conditions to be sent to all power supplies on the gun platform
- for the power supplies on the EBIS HV platform
- not for the safety chain to the Gun and Anode platform which will remain within the interlock box

Need a +24 V supply as a probe voltage of the water flow interlocks and the vacuum interlock relays. Send via the water flow and vacuum interlock relays to the AIs on the cRIO.

Note that the current from the digital output of the optical link is limited to 20 mA. Not enough to drive the Behlke control input if it's terminated with 50 ohm. Amplifier stage needed.

We don't have 5 AI and 5 AO channels in the AA Analogue Optical link to transmit the signal so only 4 will be used in the first stage

Hardware to produce

Patch panel for ground potential

Cabling

Summary

22	AO	slow	on EBIS HV		
24	AI	slow	on EBIS HV		
13	relay	slow	on EBIS HV		all low current; note that some PS are switched on by parallel (marked in blue in the table)
5	AO	fast	on EBIS HV	PXI	-10 V to +10 V, 12 bit, >2 MS/s; all need to be written in parallel
5	AI	fast	on EBIS HV	PXI	-10 V to +10 V, 12 bit, >2 MS/s; only one channel needs to be read at a time
10	DI	slow	on EBIS HV		
3	TTL output	fast	on EBIS HV	PXI	>2 MS/s, need to write in parallel
1	RS-232		on EBIS HV		

Beam diagnostics - extraction beam line

FC Faraday cup

	Element	Functionality	Speed	Interface	Physical location	GUI	Connector	Cabling	Impl. year	Comments
Alt 1	Keithley 485 picoammeter for EBIS branch FC, extraction			GPIB	On ground	Missing		Missing	2018	GPIB control
	Keithley 485 picoammeter for EBIS branch FC, injection	Control		GPIB	On ground	Missing		Missing	2019 or later	GPIB control
	Keithley 485 picoammeter for RFQ FC1	Control		GPIB	On ground	Missing		Missing	2019 or later	GPIB control
	Keithley 485 picoammeter for RFQ FC2	Control		GPIB	On ground	Missing		Missing	2019 or later	GPIB control
	Keithley 485 picoammeter TOF1	Control		GPIB	On ground	Missing		Missing	2018	GPIB control
	Keithley 485 picoammeter TOF2	Control		GPIB	On ground	Missing		Missing	2018	GPIB control
Alt 2	Keithley multiplexer 7001 with two scanner cards 7158	Control		GPIB	On ground	Missing		Missing	2018	At least two FCs should be read out in parallel
	Keithley 485 picoammeter	Control		GPIB	On ground	Missing		Missing	2018	GPIB control
	Keithley 485 picoammeter	Control		GPIB	On ground	Missing		Missing	2018	GPIB control
	FC pulse shape read out	Read	>2 MS/s	PXI	On ground	Missing		Missing	2018	< 2 V signal height, >10 bit
	FC pulse shape read out	Read	>2 MS/s	PXI	On ground	Missing		Missing	2018	< 2 V signal height, >10 bit
	FC pulse shape read out	Read	>2 MS/s	PXI	On ground	Missing		Missing	2018	< 2 V signal height, >10 bit
	FC pulse shape read out	Read	>2 MS/s	PXI	On ground	Missing		Missing	2018	< 2 V signal height, >10 bit
	Piston movement for EBIS branch FC	Write	Slow	Relay	On ground	Missing	Burndy 4	Missing	2018	Only allowed to insert FC when the BD box is out, i.e. BD box in sensor false & BD box out sensor true.
	In position for EBIS branch FC	DI	Slow	24 V	On ground	Missing		Missing	2018	Need a +24 V PS to produce a probe signal
	Piston movement for TOF branch FC	Write	Slow	Relay	On ground	Missing	Burndy 4	Missing	2018	
	In position for TOF branch FC	DI	Slow	24 V	On ground	Missing		Missing	2018	Need a +24 V PS to produce a probe signal
	Piston movement for Ion source branch FC	Write	Slow	Relay	On ground	Missing	Burndy 4	Missing	2019 or later	
	In position for Ion source branch FC	DI	Slow	24 V	On ground	Missing		Missing	2019 or later	Need a +24 V PS to produce a probe signal
	In position sensor for manually inserted BD box in EBIS branch	DI	Slow	24 V	On ground	Missing	Burndy 4	Missing	2018	Need a +24 V PS to produce a probe signal
	Out position sensor for manually inserted BD box in EBIS branch	DI	Slow	24 V	On ground	Missing		Missing	2018	Need a +24 V PS to produce a probe signal
	Trigger signal to beam chopper supply	Write	>2 MS/s	TTL signal	On ground	Missing		Missing	2018	
	Read out TOF signals									
	TOF MCP	Read	>2 MS/s	PXI	On ground	Missing		Missing	2018	< 2 V signal height, >10 bit; possibly needs some modification compared to the MCP readout implemented in TERT (by L. Hedlund)
	TOF channeltron	Read	>2 MS/s	PXI	On ground	Missing		Missing	2018	< 2 V signal height, >10 bit; probably similar to TOF MCP signal
	PS for EBIS branch MCP, voltage	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	Ramping voltage up and down should be slow; implement that by setting a low current limit in the PS?
	PS for EBIS branch MCP, voltage	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
	PS for EBIS branch MCP, current	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
	PS for EBIS branch MCP, current	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
	PS for EBIS branch MCP	On/Off	Slow	Relay	On ground	Missing	Lemo 2	Missing	2018	PS on when: 'On' command active and measure +24 V from 'Penning gauge relay in EBIS branch' (see 'Ext line vacuum & water')
	PS for EBIS branch phosphor screen, voltage	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	Ramping voltage up and down should be slow; implement that by setting a low current limit in the PS?
	PS for EBIS branch phosphor screen, voltage	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
	PS for EBIS branch phosphor screen, current	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
	PS for EBIS branch phosphor screen, current	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
	PS for EBIS branch phosphor screen	On/Off	Slow	Relay	On ground	Missing	Lemo 2	Missing	2018	PS on when: 'On' command active and measure +24 V from 'Penning gauge relay in EBIS branch' (see Ext line vacuum & water)

PS for TOF branch MCP, voltage	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	Ramping voltage up and down should be slow; implement that by setting a low current limit in the PS?
PS for TOF branch MCP, voltage	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
PS for TOF branch MCP, current	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
PS for TOF branch MCP, current	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
PS for TOF branch MCP	On/Off	Slow	Relay	On ground	Missing	Lemo 2	Missing	2018	PS on when: 'On' command active and measure +24 V from 'Penning gauge relay in TOF branch' (see 'Ext line vacuum & water')
PS forTOF branch channeltron, voltage	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	Ramping voltage up and down should be slow; implement that by setting a low current limit in the PS?
PS forTOF branch channeltron, voltage	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
PS for TOF branch channeltrom	On/Off	Slow	Relay	On ground	Missing	Lemo 2	Missing	2018	PS on when: 'On' command active and measure +24 V from 'Penning gauge relay in TOF branch' (see 'Ext line vacuum & water')
Power supply for EBIS branch FC suppressor, voltage	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
Power supply for EBIS branch FC suppressor	On/Off	Slow	Relay	On ground	Missing	Lemo 2	Missing	2018	PS on when: 'On' command active and measure +24 V from 'Penning gauge relay in EBIS branch' (see 'Ext line vacuum & water')
Power supply for RFQ branch FC suppressor, voltage	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	
Power supply for RFQ branch FC suppressor	On/Off	Slow	Relay	On ground	Missing	Lemo 2	Missing	2018	PS on when: 'On' command active and measure +24 V from 'Penning gauge relay in RFQ branch' (see 'Ext line vacuum & water')
Power supply for TOF branch FC suppressor, voltage	Write	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2019 or later	
Power supply for TOF branch FC suppressor	On/Off	Slow	Relay	On ground	Missing	Lemo 2	Missing	2019 or later	PS on when: 'On' command active and measure +24 V from 'Penning gauge relay in Ion source branch' (see 'Ext line vacuum & water')

General points

Keep emittance meter program separate from the TwinEBIS controls
Need a +24 V PS to produce a probe signal for position sensors
RFQ FC is inserted manually
Patch panel on ground
Need a 24 V PS for driving the pneumatic solenoids
Don't include controls for beam apertures in the ion injection line

Questions

Which current read-out option to go for, alt 1 or 2?
Need an application for the Wien filter: scan voltage while reading out FC, present a graph. For 2019 or later.

Summary

10	AO	slow	on gnd	
7	AI	slow	on gnd	
3	relay	slow	on gnd	>0.25 A
7	relay	slow	on gnd	low current
5	DI	slow	on gnd	
1	TTL output	fast	on gnd	PXI, >2 MS/s
5	AI	fast	on gnd	PXI <2 V >10 bit >2 MS/s; need to be able to read out two channels at the same time, not all at once
max 6	GPIB		on gnd	

Vacuum and water - extraction beam line

Element	Functionality	Speed	Control voltage	Physical location	GUI	Connector	Cabling	Impl. year	Comments	
Penning gauge EBIS branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	2 Penning and 2 Piranis per Pfeiffer TPG 300 control unit	UHV gauge (1E-4 to 1E-11 mbar) for EBIS branch of line
Pirani gauge EBIS branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018	For control cards see scem 18.40.30.535.8	Poor vacuum gauge (atmosphere to 1E-4 mbar) for EBIS branch of line
Penning gauge RFQ branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018		Dito
Pirani gauge RFQ branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018		Dito
Penning gauge TOF branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018		Dito
Pirani gauge TOF branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2018		Dito
Penning gauge ion source branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2019 or later		Dito
Pirani gauge ion source branch	Read	Slow	0-10 V	On ground	Missing	Lemo 00	Missing	2019 or later		Dito
Backing Pirani EBIS branch	Control	Slow	RS-232-C	On ground	Missing	D-Sub	Missing	2018	TPG262, 2 channels per unit, http://www.idealvac.com/files/brochures/Pfeiffer_TPG262_Operating_Instructions.pdf	Measures the pressure behind the EBIS turbo pump
Backing Pirani TOF branch	Control	Slow	RS-232-C	On ground	Missing	D-Sub	Missing	2018	Dito	Measures the pressure behind the TOF turbo pump
Backing Pirani ion source	Control	Slow	RS-232-C	On ground	Missing	D-Sub	Missing	2019 or later	Dito	Measures the pressure behind the Ion source turbo
Sector valve to EBIS	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2018	VAT valve, all Sector and Gate valves have the same type of controls	Sector valve between EBIS and ion extraction line
Sector valve to EBIS	DI	Slow	24 V	On ground	Missing		Missing	2018	see eg. https://edh.cern.ch/Document/SupplyChain/DAI/6973855	indicator for valve open
Sector valve to EBIS	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve closed
Sector valve to RFQ	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2018		Sector valve between ion extraction line and RFQ
Sector valve to RFQ	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve open
Sector valve to RFQ	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve closed
Sector valve to TOF	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2018		Sector valve between ion extraction line and TOF
Sector valve to TOF	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve open
Sector valve to TOF	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve closed
Sector valve to ion source	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2019 or later		Sector valve between ion extraction and ion source
Sector valve to ion source	DI	Slow	24 V	On ground	Missing		Missing	2019 or later		indicator for valve open
Sector valve to ion source	DI	Slow	24 V	On ground	Missing		Missing	2019 or later		indicator for valve closed
Gate valve to EBIS branch turbo	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2018		Gate valve on top of EBIS turbo
Gate valve to EBIS branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve open
Gate valve to EBIS branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve closed
Backing valve EBIS branch turbo	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2018	VAT valve, all backing valves of the same type	Valve behind EBIS turbo
Backing valve EBIS branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018	https://edh.cern.ch/edhcat/Images/309777/18.60.80.326.FTEN.pdf	indicator for valve open
Backing valve EBIS branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve closed
Gate valve to TOF branch turbo	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2018		Gate valve on top of TOF turbo
Gate valve to TOF branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve open
Gate valve to TOF branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve closed
Backing valve TOF branch turbo	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2018		Valve behind TOF turbo
Backing valve TOF branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve open
Backing valve TOF branch turbo	DI	Slow	24 V	On ground	Missing		Missing	2018		indicator for valve closed
Gate valve to ion source turbo	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2019 or later		Gate valve on top of ion source turbo
Gate valve to ion source turbo	DI	Slow	24 V	On ground	Missing		Missing	2019 or later		indicator for valve open
Gate valve to ion source turbo	DI	Slow	24 V	On ground	Missing		Missing	2019 or later		indicator for valve closed
Backing valve to ion source turbo	Write	Slow	Relay	On ground	Missing	Burndy 6	Missing	2019 or later		Valve behind ion source turbo
Backing valve to ion source turbo	DI	Slow	24 V	On ground	Missing		Missing	2019 or later		indicator for valve open
Backing valve to ion source turbo	DI	Slow	24 V	On ground	Missing		Missing	2019 or later		indicator for valve closed

Include in Labview or not?

Control roughing pump for EBIS branch	Control	Slow	RS-485	On ground	Missing	D-sub	Missing	2018	Pfeiffer ACP15 https://www.pfeiffer-vacuum.com/productPdfs/V5SATSMTRF.en.pdf	Roughing pump that backs (in series with) EBIS turbo
Control turbo pump for EBIS branch	Control	Slow	RS-485	On ground	Missing	D-sub	Missing	2018	Pfeiffer TC600 http://www.idealvac.com/files/manualsII/TMH-TMU_071P.pdf	Turbo pump that provides high vacuum in EBIS branch
Control roughing pump for TOF branch	Write	Slow	Relay	On ground	Missing	Burndy 4	Missing	2018	Edwards XDS35i from BNL - will we get it back? https://www.lesker.com/newweb/vacuum_pumps/pdf/manuals/xds35i%20isue%20e%20manual.pdf	Control of roughing pump that backs (in series with) TOF turbo
Control roughing pump for TOF branch	DI	Slow	24 V	On ground	Missing		Missing	2018		Read status of roughing pump
Control turbo pump for TOF branch	Control	Slow	RS-485	On ground	Missing	D-sub	Missing	2018	Pfeiffer HiPace 700 from BNL - will we get it back?	Turbo pump that provides high vacuum for TOF branch
Control roughing pump for Ion source	Control	Slow	RS-485	On ground	Missing	D-sub	Missing	2019 or later	Order a ACP15?	Roughing pump that backs (in series with) Ion source turbo
Control turbo pump for Ion source	Control	Slow	RS-485	On ground	Missing	D-sub	Missing	2019 or later	Order a Pfeiffer HiPace?	Turbo pump that provides high vacuum for Ion source branch
Water flow for ion source	DI	Slow	24 V	On ground	Missing	Burndy 4	Missing	2019 or later	Display status in GUI	Check if water flows in ion source
Water flow for separator magnet	DI	Slow	24 V	On ground	Missing	Burndy 4	Missing	2019 or later	Display status in GUI	Check if water flows in the separator magnet
Temperature indicator for separator magnet	DI	Slow	24 V	On ground	Missing	Burndy 4	Missing	2019 or later	Display status in GUI	Check temperature in the separator magnet
Relay from EBIS branch Penning gauge	DI	Slow	24 V	On ground	Missing	Burndy 4	Missing	2018	Display status in GUI	Indicates if the vacuum in the sector is good enough for applying voltages
Relay from Ion source branch Penning gauge	DI	Slow	24 V	On ground	Missing		Missing	2018	Display status in GUI	Dito
Relay from TOF branch Penning gauge	DI	Slow	24 V	On ground	Missing	Burndy 4	Missing	2018	Display status in GUI	Dito
Relay from RFQ branch Penning gauge	DI	Slow	24 V	On ground	Missing		Missing	2018	Display status in GUI	Dito

General comments

In case the vacuum controls are run by Labview they have to be failsafe from a machine protectin point of view, that is:

- not get stuck in some indetermined state
- continue to run even if the communication to the cRIO is abrupted
- follow a special sequence once power returns after a power cut

The Labview relays should handle 24 V, 0.3 A

Need a +24 V supply as a probe voltage for all valve positions. Sent via the position relay in the valve to the AI on the cRIO.

Don't have dedicated relays from the turbo backing Piranis but use pressure read-out from compact Pirani gauges

Hardware to produce

Patch panel for ground potential

Patch panel for ion source potential

Cabling

Need a hardware interlock box for the vacuum relays at ground

Questions / To do

Need to establish control options for the roughing and turbo pumps. What interfac to use? Read out 'Up-to-speed' for example.

Additional signals might be needed for the pump controls - to be verified

Need to establish operational logic for the vacuum

The 'Gate valve to EBIS' needs conditions from both 'EBIS HV platform' and ground (the same signal as needed for 'EBIS HV' PS in 'Ext line power supplies')

No LV concern How to program the Penning gauges so they switch off automatically about 5E-5 mbar? (done in the controller directly not via Labview)

No LV concern Need to establish functionality of the Temperature indicator for the separator magnet

Summary

28	DI	slow	on gnd	
8	AI	slow	on gnd	
11	relay	slow	on gnd	>0.25 A
2	RS232		on gnd	
5	RS485		on gnd	

we may need a few exta for reading pump status

Power supplies - extraction beam line

Element	Functionality	Speed	Control voltage	Connector	Physical location	Interlock signal from	GUI	Cabling	Implementation year	Comment
EBIS HV	Write voltage	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2018	
EBIS HV	Read voltage	Slow	0-10 V	Lemo 00	On ground				2018	
EBIS HV	Write current	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2018	
EBIS HV	Read current	Slow	0-10 V	Lemo 00	On ground				2018	
EBIS HV	On/Off power supply	Slow	Relay	Lemo 2	On ground				2018	The safety chain is handled with Interlock_box_2. Labview only feeds On/Off by setting a relay. The relay should handle 24 V and 0.25 A.
Gridded lens EBIS	Write voltage	Fast	0-10 V		On ground		Missing	Missing	2018	
Gridded lens EBIS	Read voltage	Fast	0-10 V		On ground				2018	
Gridded lens EBIS	On/Off power supply	Slow	Relay		On ground	Penning gauge relay from EBIS branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from EBIS branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector EBIS up	Write voltage	Fast	-10 to +10 V		On ground		Missing	Missing	2018	
Vertical deflector EBIS up	Read voltage	Fast	-10 to +10 V		On ground				2018	
Vertical deflector EBIS up	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from EBIS branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from EBIS branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector EBIS down	Write voltage	Fast	-10 to +10 V		On ground		Missing	Missing	2018	Opposite voltage to Vertical deflector EBIS up
Vertical deflector EBIS down	Read voltage	Fast	-10 to +10 V		On ground				2018	
Vertical deflector EBIS down	On/Off power supply	Slow	Relay	Lemo 2	On ground				2018	Controlled by same output relay as Vertical deflector EBIS up
Horizontal bender EBIS left	Write voltage	Fast	-10 to +10 V		On ground		Missing	Missing	2018	
Horizontal bender EBIS left	Read voltage	Fast	-10 to +10 V		On ground				2018	
Horizontal bender EBIS left	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from EBIS branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from EBIS branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Horizontal bender EBIS right	Write voltage	Fast	-10 to +10 V		On ground		Missing	Missing	2018	Opposite voltage to Horizontal bender EBIS left
Horizontal bender EBIS right	Read voltage	Fast	-10 to +10 V		On ground				2018	
Horizontal bender EBIS right	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from EBIS branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from EBIS branch Penning gauge' (see Sheet:'Ext line vacuum &water')
Gridded lens ToF	Write voltage	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2018	
Gridded lens ToF	Read voltage	Slow	0-10 V	Lemo 00	On ground				2018	
Gridded lens ToF	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from TOF branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from TOF branch Penning gauge' (see Sheet:'Ext line vauum & water')
Einzel lens RFQ	Write voltage	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2018	
Einzel lens RFQ	Read voltage	Slow	0-10 V	Lemo 00	On ground				2018	
Einzel lens RFQ	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from RFQ branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from RFQ branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector RFQ up	Write voltage	Slow	-10 to +10 V	Lemo 00	On ground		Missing	Missing	2018	
Vertical deflector RFQ up	Read voltage	Slow	-10 to +10 V	Lemo 00	On ground				2018	
Vertical deflector RFQ up	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from EBIS branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from EBIS branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector RFQ up	Polarity switching	Slow	TTL	Lemo 00	On ground				2018	By setting the TTL signal the output polarity is chosen. Only allowed to change the signal when the power supply is set to 0 V output.
Vertical deflector RFQ down	Write voltage	Slow	-10 to +10 V	Lemo 00	On ground		Missing	Missing	2018	Opposite voltage to Vertical deflector RFQ up
Vertical deflector RFQ down	Read voltage	Slow	-10 to +10 V	Lemo 00	On ground				2018	
Vertical deflector RFQ down	On/Off power supply	Slow	Relay	Lemo 2	On ground				2018	Controlled by same output relay as Vertical deflector RFQ up
Vertical deflector RFQ down	Polarity switching	Slow	TTL	Lemo 00	On ground				2018	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.

Horizontal deflector RFQ left	Write voltage	Slow	-10 to +10 V	Lemo 00	On ground		Missing	Missing	2018	
Horizontal deflector RFQ left	Read voltage	Slow	-10 to +10 V	Lemo 00	On ground				2018	
Horizontal deflector RFQ left	On/Off power supply	Slow	Relay	Lemo 2	On ground				2018	Controlled by same output relay as Vertical deflector RFQ up
Horizontal deflector RFQ left	Polarity switching	Slow	TTL	Lemo 00	On ground				2018	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Horizontal deflector RFQ right	Write voltage	Slow	-10 to +10 V	Lemo 00	On ground		Missing	Missing	2018	Opposite voltage to Horizontal deflector RFQ left
Horizontal deflector RFQ right	Read voltage	Slow	-10 to +10 V	Lemo 00	On ground				2018	
Horizontal deflector RFQ right	On/Off power supply	Slow	Relay	Lemo 2	On ground				2018	Controlled by same output relay as Vertical deflector RFQ up
Horizontal deflector RFQ right	Polarity switching	Slow	TTL	Lemo 00	On ground				2018	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Gridded lens RFQ	Write voltage	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2018	
Gridded lens RFQ	Read voltage	Slow	0-10 V	Lemo 00	On ground				2018	
Gridded lens RFQ	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from RFQ branch			2018	PS on when: 'On' command active and +24 V measured on 'Relay from RFQ branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector ion 1 up	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Vertical deflector ion 1 up	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Vertical deflector ion 1 up	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from ion source branch			2019 or later	PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector ion 1 up	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Vertical deflector ion 1 down	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	Opposite voltage to Horizontal deflector 1 up
Vertical deflector ion 1 down	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Vertical deflector ion 1 down	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Horizontal deflector ion 1 up
Vertical deflector ion 1 down	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Horizontal deflector ion 1 left	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Horizontal deflector ion 1 left	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Horizontal deflector ion 1 left	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Horizontal deflector ion 1 up
Horizontal deflector ion 1 left	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Horizontal deflector ion 1 right	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	Opposite voltage to Horizontal deflector 1 left
Horizontal deflector ion 1 right	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Horizontal deflector ion 1 right	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Horizontal deflector ion 1 up
Horizontal deflector ion 1 right	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Vertical deflector ion 2 up	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Vertical deflector ion 2 up	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Vertical deflector ion 2 up	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from ion source branch			2019 or later	PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector ion 2 up	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Vertical deflector ion 2 down	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	Opposite voltage to Vertical deflector ion 1 up
Vertical deflector ion 2 down	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Vertical deflector ion 2 down	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Vertical deflector ion 1 up
Vertical deflector ion 2 down	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Horizontal deflector ion 2 left	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Horizontal deflector ion 2 left	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Horizontal deflector ion 2 left	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Vertical deflector ion 1 up
Horizontal deflector ion 2 left	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Horizontal deflector ion 2 right	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	Opposite voltage to Horizontal deflector ion 2 left
Horizontal deflector ion 2 right	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Horizontal deflector ion 2 right	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Vertical deflector ion 1 up
Horizontal deflector ion 2 right	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.

Lens ion source line	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Lens ion source line	Read	Slow	0-10 V		On ground				2019 or later	
Lens ion source line	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from ion source branch			2019 or later	PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet:'Ext line power vacuum & water')
Separator magnet voltage	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	Tentative. In case a Wienfilter is used, the current settings will be obsolete
Separator magnet voltage	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	Tentative
Separator magnet current	Write	Slow	0-10 V	Lemo 00	On ground				2019 or later	Tentative
Separator magnet current	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	Tentative
Separator magnet	On/Off power supply	Slow	Relay	Lemo 2	On ground	Water and temperature interlock			2019 or later	PS on when: 'On' command active and +24 V measured on 'Separator water interlock' and +24 V measured on 'Separator temperature interlock' (see Sheet:'Ext line vacuum & water')
Ion source focussing	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Ion source focussing	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Ion source focussing	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from ion source branch			2019 or later	PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector ion 3 up	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Vertical deflector ion 3 up	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Vertical deflector ion 3 up	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from ion source branch			2019 or later	PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Vertical deflector ion 3 up	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Vertical deflector ion 3 down	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Vertical deflector ion 3 down	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Vertical deflector ion 3 down	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Vertical deflector ion 3 up
Vertical deflector ion 3 down	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Horizontal deflector ion 3 left	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Horizontal deflector ion 3 left	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Horizontal deflector ion 3 left	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Vertical deflector ion 3 up
Horizontal deflector ion 3 left	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Horizontal deflector ion 3 right	Write	Slow	0-10 V	Lemo 00	On ground		Missing	Missing	2019 or later	
Horizontal deflector ion 3 right	Read	Slow	0-10 V	Lemo 00	On ground				2019 or later	
Horizontal deflector ion 3 right	On/Off power supply	Slow	Relay	Lemo 2	On ground				2019 or later	Controlled by same output relay as Vertical deflector ion 3 up
Horizontal deflector ion 3 right	Polarity switching	Slow	TTL	Lemo 00	On ground				2019 or later	By setting the TTL signal the output polarity is chose. Only allowed to change the signal when the power supply is set to 0 V output.
Ion source bias voltage	Write	Slow	0-10 V	Lemo 00	On ion source platform		Missing	Missing	2019 or later	Tentative
Ion source bias voltage	Read	Slow	0-10 V	Lemo 00	On ion source platform				2019 or later	Tentative
Ion source bias current	Write	Slow	0-10 V	Lemo 00	On ion source platform				2019 or later	Tentative
Ion source bias current	Read	Slow	0-10 V	Lemo 00	On ion source platform				2019 or later	Tentative
In source bias	On/Off power supply	Slow	Relay	Lemo 2	On ion source platform	Penning gauge relay from ion source branch			2019 or later	Tentative. PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Ion source heating current	Write	Slow	0-10 V	Lemo 00	On ion source platform		Missing	Missing	2019 or later	Tentative
Ion source heating current	Read	Slow	0-10 V	Lemo 00	On ion source platform				2019 or later	Tentative
Ion source heating voltage	Write	Slow	0-10 V	Lemo 00	On ion source platform				2019 or later	Tentative
Ion source heating voltage	Read	Slow	0-10 V	Lemo 00	On ion source platform				2019 or later	Tentative
Ion source heating	On/Off power supply	Slow	Relay	Lemo 2	On ion source platform	Penning gauge relay from ion source branch and Water flow for ion source			2019 or later	Tentative. PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet:'Ext line vacuum & water')
Wien filter	Write	Slow		Lemo 00	On ground		Missing	Missing	2019 or later	
Wien filter	Read	Slow		Lemo 00	On ground				2019 or later	
Wien filter	On/Off power supply	Slow	Relay	Lemo 2	On ground	Penning gauge relay from ion source branch			2019 or later	PS on when: 'On' command active and +24 V measured on 'Relay from Ion source branch Penning gauge' (see Sheet: Ext line vacuum & water)

General comments

All power supplies vacuum interlocked, except for Separator magnet that is water and temperature interlocked

Instead of taking the vacuum interlocks from the reading of the Penning / Full range gauges one should rely on relays in the gauge controllers. See comments to each On/Off signal above

All On/off should be in series with the Interlock

Hardware to produce

Patch panel for ground potential

Patch panel for ion source potential

Cabling

Questions / To do

Specify ion injection line and ion separation line using the separator magnet

At some point 2019 or later, elements in the Ion source line may be vacuum interlocked by the Penning gauge relay from the TOF branch instead of the Penning gauge relay from the Ion source branch

Summary

26	AO	slow	on gnd		
26	AI	slow	on gnd		
16	TTL	slow	on gnd		
1	relay	slow	on gnd	>0.25 A	
16	relay	slow	on gnd	low current	note that some PS are switched on in parallel (marked in blue in the table)
5	AO	fast	on gnd	PXI	-10 V to +10 V, 12 bit, >100 kS/s; all need to be written in parallel
5	AI	fast	on gnd	PXI	-10 V to +10 V, 12 bit, >100 kS/s; sufficient to sample one at a time to inspect the wave form
4	AO	slow	on Ion source platform		exclude them from work 2018; need another cRIO on separate platform
4	AI	slow	on Ion source platform		exclude them from work 2018; need another cRIO on separate platform
2	relay	slow	on Ion source platform	low current	exclude them from work 2018; need another cRIO on separate platform

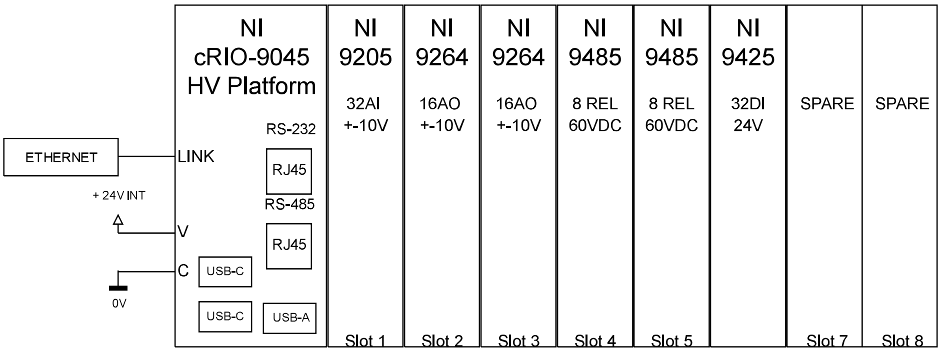
Appendix E

Hardware Wiring

This appendix contains the wiring diagram for the cRIO

1. High Voltage
2. Beam Diagnostic & Vacuum
3. Beam Optics
4. Gun

cRIO Module setup and connection



TwinEBIS	ECHELLE SCALE	SH-CERN	NOM/NAME	DATE
cRIO HV-Platform		APPRO.		
		CONTROL		
		DES/DRA.	*Steen*	2019-05-03
		REMPLACE/REPLACES		
				IND.

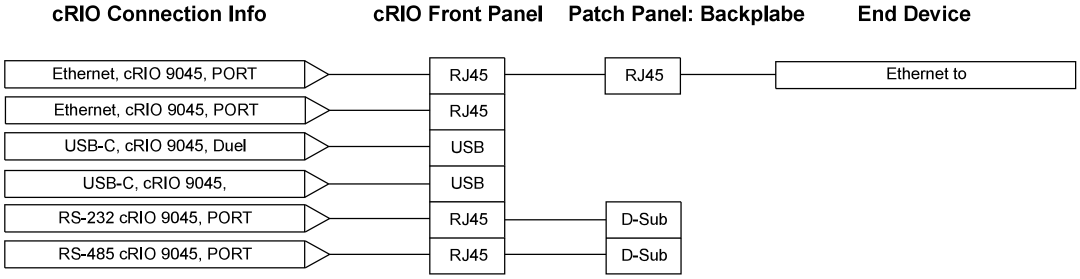
Connection Diagram from the cRIO Front Panel

Information

cRIO: HV-platform
Perspective: cRIO Front panel

Definitions

D-Sub X = D-sub connector



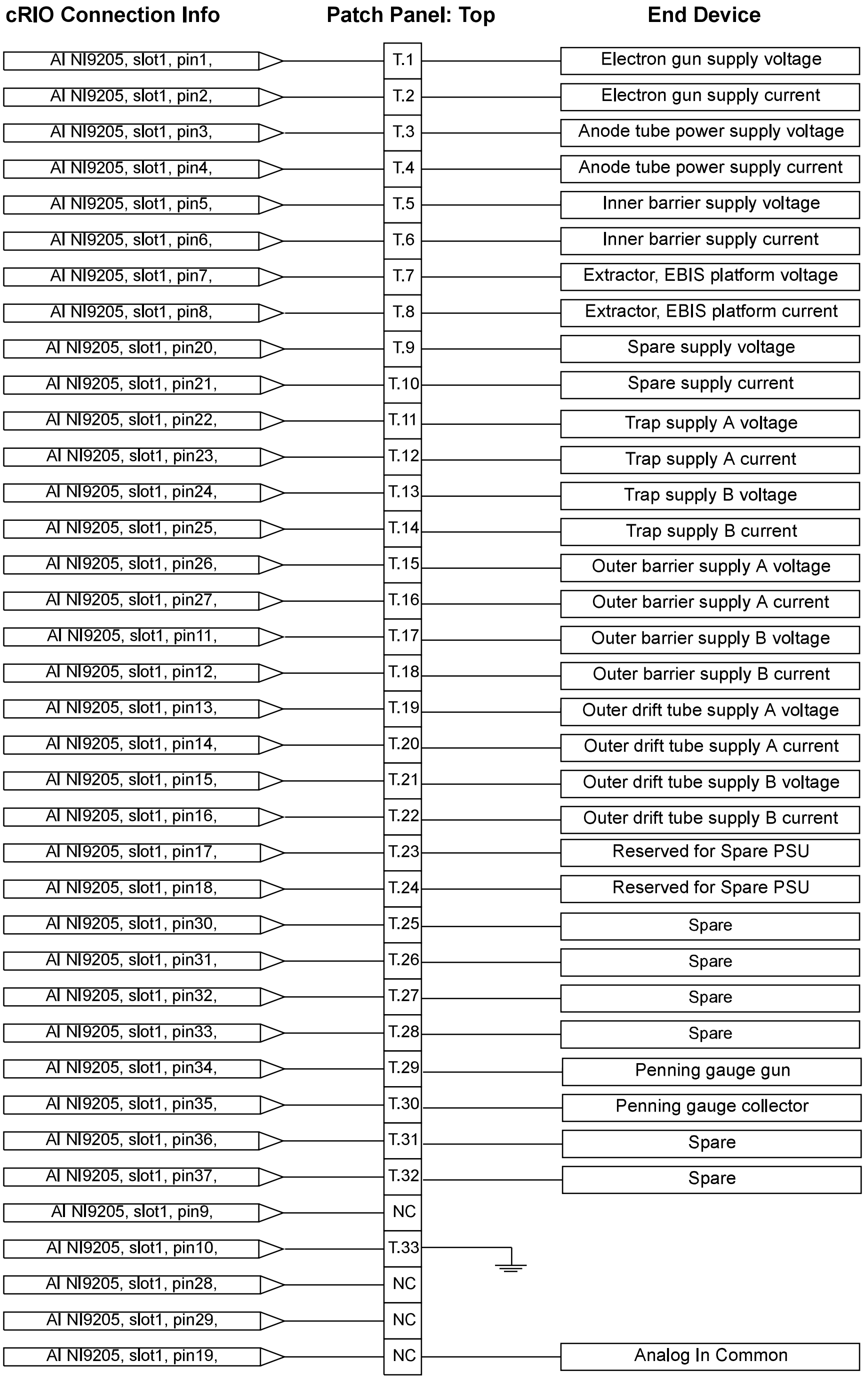
Connection Diagram for the Analog Input Module

Information

cRIO: HV-Platform
Perspective: Analog Inputs are in ascending order

Definitions

T.x = Top Screw Terminal



cRIO Connection Info	Patch Panel: Top	End Device
AI NI9205, slot1, pin1,	T.1	Electron gun supply voltage
AI NI9205, slot1, pin2,	T.2	Electron gun supply current
AI NI9205, slot1, pin3,	T.3	Anode tube power supply voltage
AI NI9205, slot1, pin4,	T.4	Anode tube power supply current
AI NI9205, slot1, pin5,	T.5	Inner barrier supply voltage
AI NI9205, slot1, pin6,	T.6	Inner barrier supply current
AI NI9205, slot1, pin7,	T.7	Extractor, EBIS platform voltage
AI NI9205, slot1, pin8,	T.8	Extractor, EBIS platform current
AI NI9205, slot1, pin20,	T.9	Spare supply voltage
AI NI9205, slot1, pin21,	T.10	Spare supply current
AI NI9205, slot1, pin22,	T.11	Trap supply A voltage
AI NI9205, slot1, pin23,	T.12	Trap supply A current
AI NI9205, slot1, pin24,	T.13	Trap supply B voltage
AI NI9205, slot1, pin25,	T.14	Trap supply B current
AI NI9205, slot1, pin26,	T.15	Outer barrier supply A voltage
AI NI9205, slot1, pin27,	T.16	Outer barrier supply A current
AI NI9205, slot1, pin11,	T.17	Outer barrier supply B voltage
AI NI9205, slot1, pin12,	T.18	Outer barrier supply B current
AI NI9205, slot1, pin13,	T.19	Outer drift tube supply A voltage
AI NI9205, slot1, pin14,	T.20	Outer drift tube supply A current
AI NI9205, slot1, pin15,	T.21	Outer drift tube supply B voltage
AI NI9205, slot1, pin16,	T.22	Outer drift tube supply B current
AI NI9205, slot1, pin17,	T.23	Reserved for Spare PSU
AI NI9205, slot1, pin18,	T.24	Reserved for Spare PSU
AI NI9205, slot1, pin30,	T.25	Spare
AI NI9205, slot1, pin31,	T.26	Spare
AI NI9205, slot1, pin32,	T.27	Spare
AI NI9205, slot1, pin33,	T.28	Spare
AI NI9205, slot1, pin34,	T.29	Penning gauge gun
AI NI9205, slot1, pin35,	T.30	Penning gauge collector
AI NI9205, slot1, pin36,	T.31	Spare
AI NI9205, slot1, pin37,	T.32	Spare
AI NI9205, slot1, pin9,	NC	
AI NI9205, slot1, pin10,	T.33	
AI NI9205, slot1, pin28,	NC	
AI NI9205, slot1, pin29,	NC	
AI NI9205, slot1, pin19,	NC	Analog In Common

Connection Diagram for the Analog Output Module 1

Information

cRIO: HV-Platform
Perspective: Analog Outputs are in ascending order

Definitions

T.x = Top Screw Terminal

cRIO Connection Info	Patch Panel: Top	End Device
AO NI9264, slot2, pin1,	T.35	Electron gun supply voltage
AO NI9264, slot2, pin2,	T.36	Electron gun supply current
AO NI9264, slot2, pin3,	T.37	Anode tube power supply voltage
AO NI9264, slot2, pin4,	T.38	Anode tube power supply current
AO NI9264, slot2, pin5,	T.39	Inner barrier supply voltage
AO NI9264, slot2, pin6,	T.40	Inner barrier supply current
AO NI9264, slot2, pin7,	T.41	Extractor, EBIS platform voltage
AO NI9264, slot2, pin8,	T.42	Extractor, EBIS platform current
AO NI9264, slot2, pin11,	T.43	Spare supply voltage
AO NI9264, slot2, pin12,	T.44	Spare supply current
AO NI9264, slot2, pin13,	T.45	Trap supply A voltage
AO NI9264, slot2, pin14,	T.46	Trap supply A current
AO NI9264, slot2, pin15,	T.47	Trap supply B voltage
AO NI9264, slot2, pin16,	T.48	Trap supply B current
AO NI9264, slot2, pin17,	T.49	Outer barrier supply A voltage
AO NI9264, slot2, pin18,	T.50	Outer barrier supply A current
AO NI9264, slot2, pin19,	T.68	Analog Out Common Ground
AO NI9264, slot2, pin20,	NC	
AO NI9264, slot2, pin21,	NC	
AO NI9264, slot2, pin22,	NC	
AO NI9264, slot2, pin23,	NC	
AO NI9264, slot2, pin24,	NC	
AO NI9264, slot2, pin25,	NC	
AO NI9264, slot2, pin26,	NC	
AO NI9264, slot2, pin27,	NC	
AO NI9264, slot2, pin30,	NC	
AO NI9264, slot2, pin31,	NC	
AO NI9264, slot2, pin32,	NC	
AO NI9264, slot2, pin33,	NC	
AO NI9264, slot2, pin34,	NC	
AO NI9264, slot2, pin35,	NC	
AO NI9264, slot2, pin36,	NC	
AO NI9264, slot2, pin37,	NC	
AO NI9264, slot2, pin9,	NC	
AO NI9264, slot2, pin10,	NC	
AO NI9264, slot2, pin28,	NC	
AO NI9264, slot2, pin29,	NC	

Connection Diagram for the Analog Output Module 2

Information

cRIO: HV-Platform
Perspective: Analog Outputs are in ascending order

Definitions

T.x = Top Screw Terminal

cRIO Connection Info	Patch Panel: Top	End Device
AO NI9264, slot3, pin1,	T.51	Outer barrier supply B voltage
AO NI9264, slot3, pin2,	T.52	Outer barrier supply B current
AO NI9264, slot3, pin3,	T.53	Outer drift tube supply A voltage
AO NI9264, slot3, pin4,	T.54	Outer drift tube supply A current
AO NI9264, slot3, pin5,	T.55	Outer drift tube supply B voltage
AO NI9264, slot3, pin6,	T.56	Outer drift tube supply B current
AO NI9264, slot3, pin7,	T.57	Reserved for Spare
AO NI9264, slot3, pin8,	T.58	Reserved for Spare PSU
AO NI9264, slot3, pin11,	T.59	Spare
AO NI9264, slot3, pin12,	T.60	Spare
AO NI9264, slot3, pin13,	T.61	Spare
AO NI9264, slot3, pin14,	T.62	Spare
AO NI9264, slot3, pin15,	T.63	Spare
AO NI9264, slot3, pin16,	T.64	Spare
AO NI9264, slot3, pin17,	T.65	Spare
AO NI9264, slot3, pin18,	T.66	Spare
AO NI9264, slot3, pin19,	T.67	Analog Out Common Ground
AO NI9264, slot3, pin20,	NC	
AO NI9264, slot3, pin21,	NC	
AO NI9264, slot3, pin22,	NC	
AO NI9264, slot3, pin23,	NC	
AO NI9264, slot3, pin24,	NC	
AO NI9264, slot3, pin25,	NC	
AO NI9264, slot3, pin26,	NC	
AO NI9264, slot3, pin27,	NC	
AO NI9264, slot3, pin30,	NC	
AO NI9264, slot3, pin31,	NC	
AO NI9264, slot3, pin32,	NC	
AO NI9264, slot3, pin33,	NC	
AO NI9264, slot3, pin34,	NC	
AO NI9264, slot3, pin35,	NC	
AO NI9264, slot3, pin36,	NC	
AO NI9264, slot3, pin37,	NC	
AO NI9264, slot3, pin9,	NC	
AO NI9264, slot3, pin10,	NC	
AO NI9264, slot3, pin28,	NC	
AO NI9264, slot3, pin29,	NC	

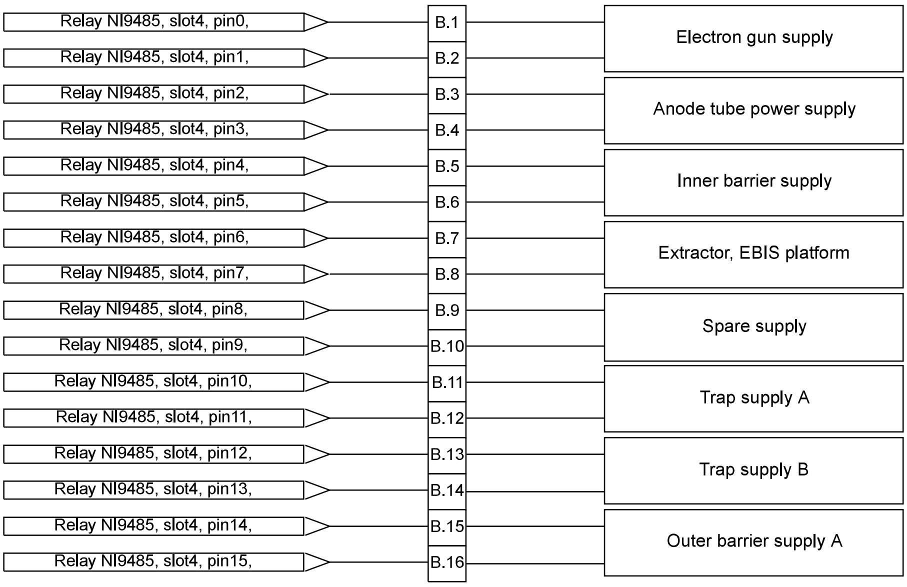
Connection Diagram for the Relay Module 1

Information

cRIO: HV-Platform
Perspective: Relays are in ascending order

Definitions

B.x = Bottom Screw Terminal



cRIO Connection Info	Patch Panel: Bottom	End Device
Relay NI9485, slot4, pin0,	B.1	Electron gun supply
Relay NI9485, slot4, pin1,	B.2	
Relay NI9485, slot4, pin2,	B.3	Anode tube power supply
Relay NI9485, slot4, pin3,	B.4	
Relay NI9485, slot4, pin4,	B.5	Inner barrier supply
Relay NI9485, slot4, pin5,	B.6	
Relay NI9485, slot4, pin6,	B.7	Extractor, EBIS platform
Relay NI9485, slot4, pin7,	B.8	
Relay NI9485, slot4, pin8,	B.9	Spare supply
Relay NI9485, slot4, pin9,	B.10	
Relay NI9485, slot4, pin10,	B.11	Trap supply A
Relay NI9485, slot4, pin11,	B.12	
Relay NI9485, slot4, pin12,	B.13	Trap supply B
Relay NI9485, slot4, pin13,	B.14	
Relay NI9485, slot4, pin14,	B.15	Outer barrier supply A
Relay NI9485, slot4, pin15,	B.16	

Connection Diagram for the Relay Module 2

Information

cRIO: HV-Platform
Perspective: Relays are in ascending order

Definitions

B.x = Bottom Screw Terminal

cRIO Connection Info	Patch Panel: Bottom	End Device
Relay NI9485, slot5, pin0,	B.17	Outer barrier supply B
Relay NI9485, slot5, pin1,	B.18	
Relay NI9485, slot5, pin2,	B.19	Outer drift tube supply A
Relay NI9485, slot5, pin3,	B.20	
Relay NI9485, slot5, pin4,	B.21	Outer drift tube supply B
Relay NI9485, slot5, pin5,	B.22	
Relay NI9485, slot5, pin6,	B.23	Resverve
Relay NI9485, slot5, pin7,	B.24	
Relay NI9485, slot5, pin8,	B.25	Spare
Relay NI9485, slot5, pin9,	B.26	
Relay NI9485, slot5, pin10,	B.27	TREK 1-4
Relay NI9485, slot5, pin11,	B.28	
Relay NI9485, slot5, pin12,	B.29	Adaptor electrode
Relay NI9485, slot5, pin13,	B.30	
Relay NI9485, slot5, pin14,	B.31	Spare
Relay NI9485, slot5, pin15,	B.32	

Connection Diagram for the Digital Input Module

Information
cRIO: HV-platform
Perspective: Digital input are in ascending order

Definitions
B.x = Bottom Screw Terminal

cRIO Connection Info	Patch Panel: Bottom	End Device
DI NI9425, slot6, pin1,	B.33	D-sub 15 Connection Pin 2
DI NI9425, slot6, pin2,	B.34	D-sub 15 Connection Pin 3
DI NI9425, slot6, pin3,	B.35	Water turbo
DI NI9425, slot6, pin4,	B.36	Water bore
DI NI9425, slot6, pin5,	B.37	Water collector
DI NI9425, slot6, pin6,	B.38	Water gun
DI NI9425, slot6, pin7,	B.39	Cathode heating interlock
DI NI9425, slot6, pin8,	B.40	D-sub 15 Connection Pin 9
DI NI9425, slot6, pin11,	B.41	D-sub 15 Connection Pin 10
DI NI9425, slot6, pin12,	B.42	Relay from anode platform cage
DI NI9425, slot6, pin13,	B.43	Relay Gun-platform from Door
DI NI9425, slot6, pin14,	B.44	Relay from gun Pirani gauge
DI NI9425, slot6, pin15,	B.45	Relay from gun Penning gauge
DI NI9425, slot6, pin16,	B.46	Relay from collector Penning gauge
DI NI9425, slot6, pin17,	B.47	
DI NI9425, slot6, pin18,	B.48	
DI NI9425, slot6, pin20,	B.49	
DI NI9425, slot6, pin21,	B.50	
DI NI9425, slot6, pin22,	NC	
DI NI9425, slot6, pin23,	NC	
DI NI9425, slot6, pin24,	NC	
DI NI9425, slot6, pin25,	NC	
DI NI9425, slot6, pin26,	NC	
DI NI9425, slot6, pin27,	NC	
DI NI9425, slot6, pin30,	NC	
DI NI9425, slot6, pin31,	NC	
DI NI9425, slot6, pin32,	NC	
DI NI9425, slot6, pin33,	NC	
DI NI9425, slot6, pin34,	NC	
DI NI9425, slot6, pin35,	NC	
DI NI9425, slot6, pin36,	NC	
DI NI9425, slot6, pin37,	NC	
DI NI9425, slot6, pin9,	B.51	⏚
DI NI9425, slot6, pin10,	NC	
DI NI9425, slot6, pin28,	NC	
DI NI9425, slot6, pin29,	NC	
DI NI9425, slot6, pin19,	NC	

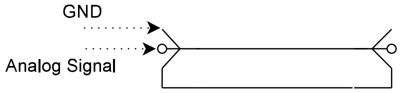
Connection Diagram for the backplane of the box

Information

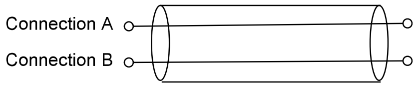
cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Back panel Connectors are in ascending order

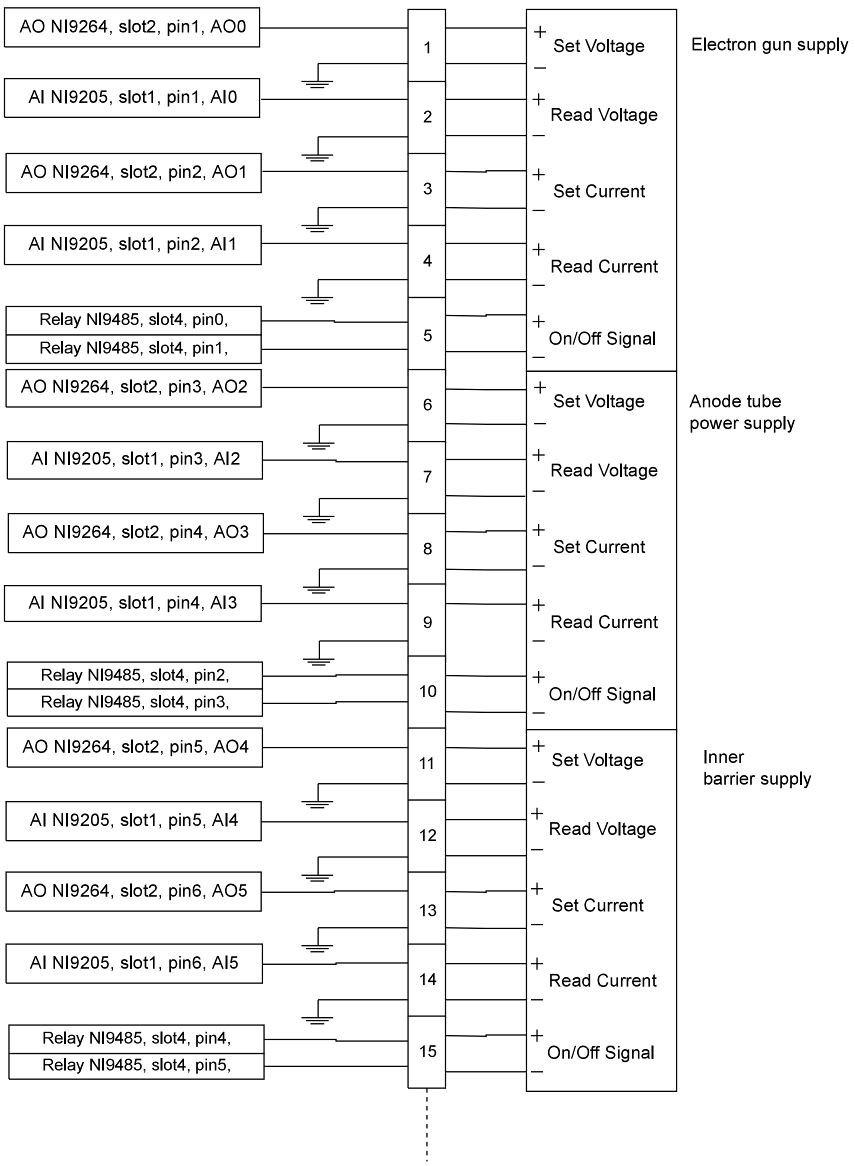
Definitions

Most LEMOs are 00 and are connect and wired like this.

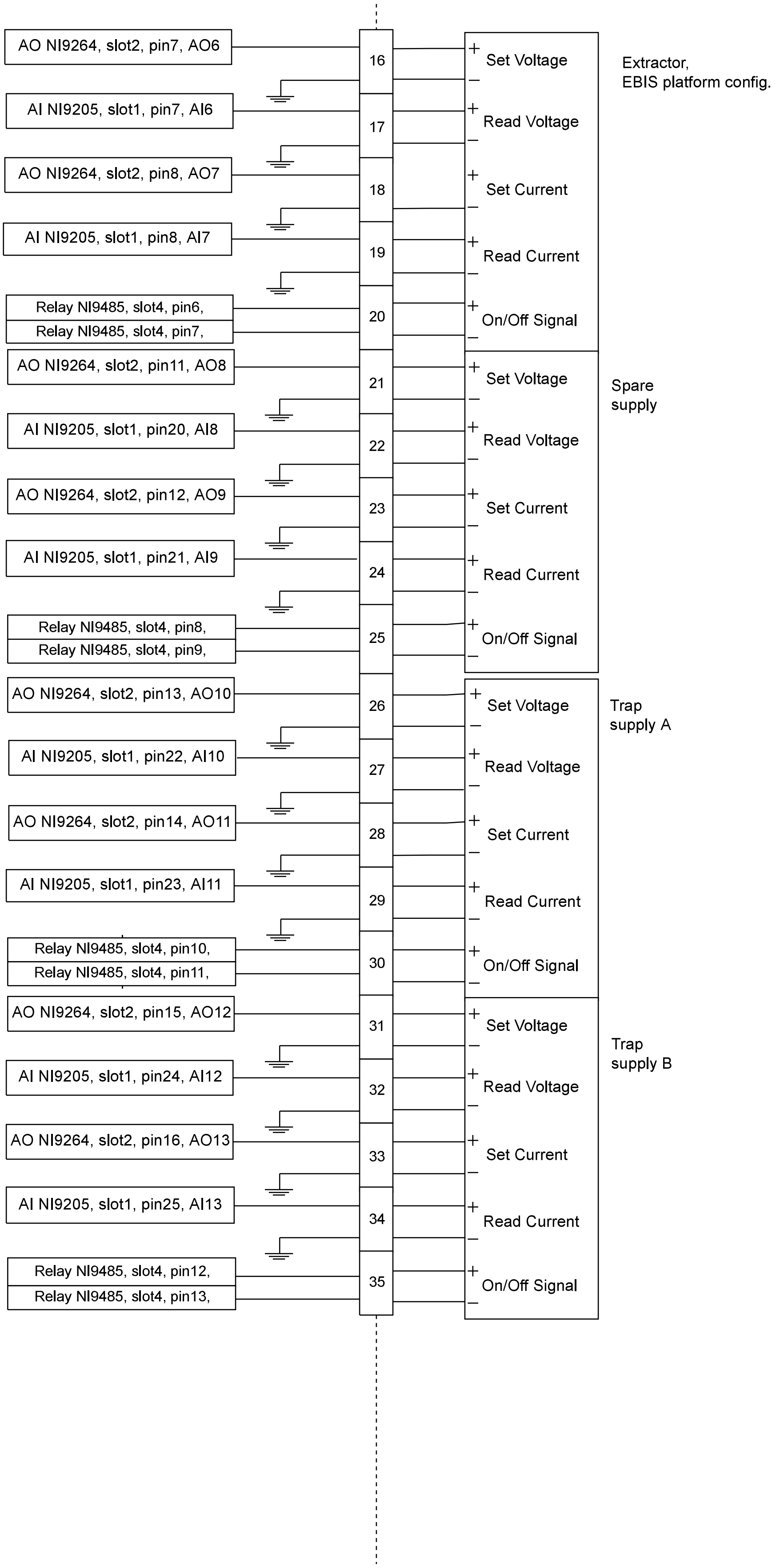


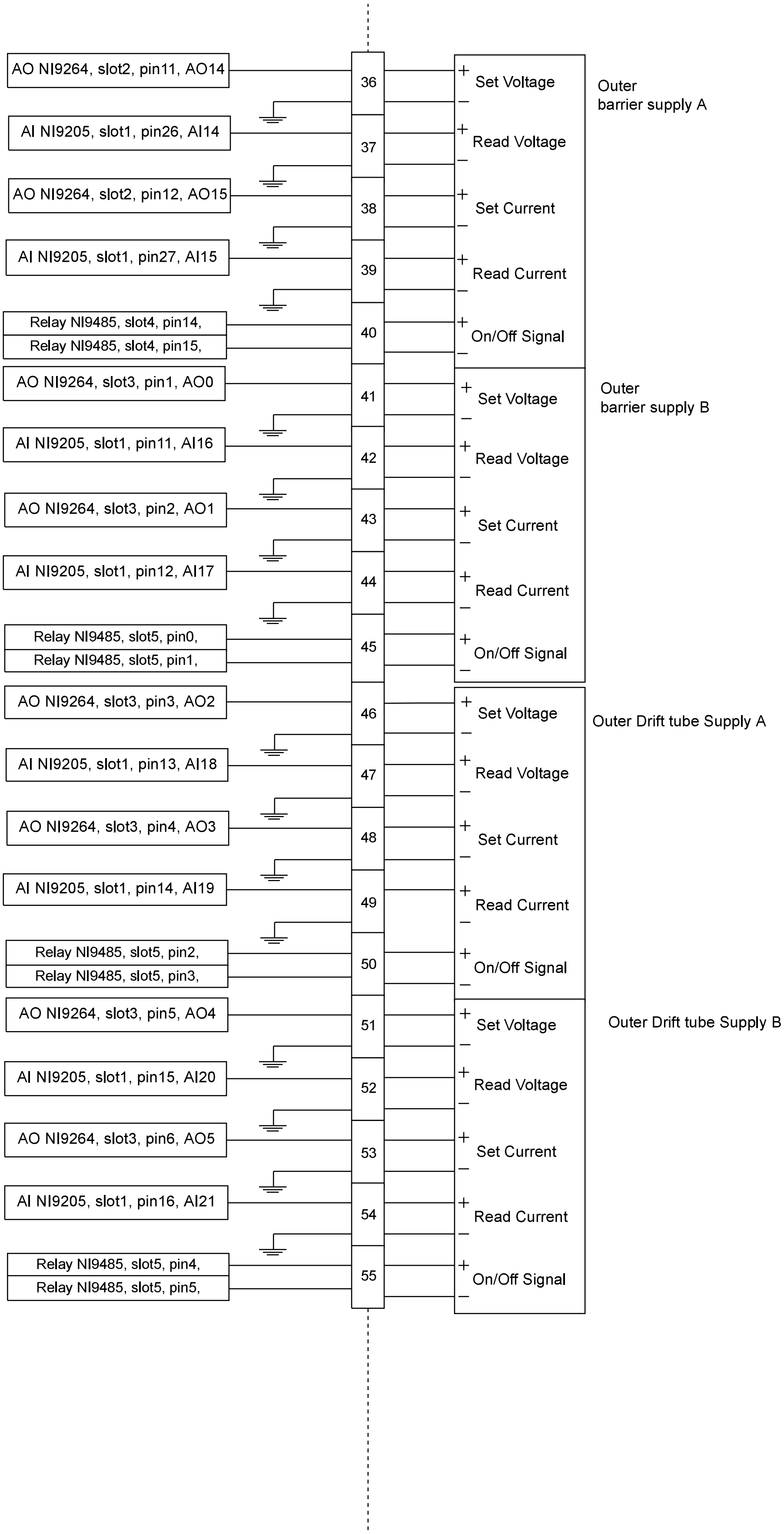
The relay uses LEMO 2 and has this type of connection and wiring

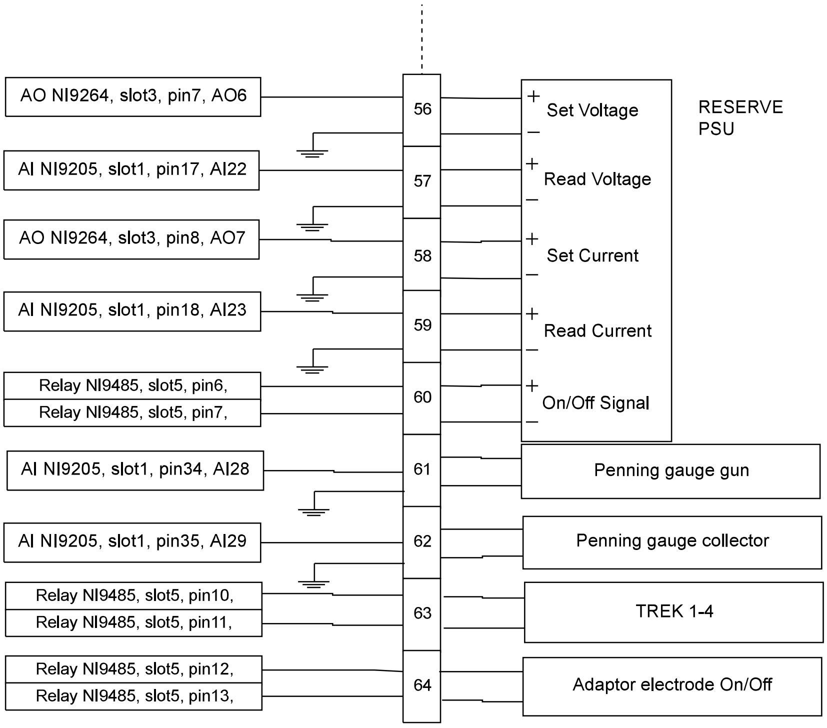




cRIO Connection Info	Patch Panel: Backplane	End Device	
AO NI9264, slot2, pin1, AO0	1	+ Set Voltage −	Electron gun supply
AI NI9205, slot1, pin1, AI0	2	+ Read Voltage −	
AO NI9264, slot2, pin2, AO1	3	+ Set Current −	
AI NI9205, slot1, pin2, AI1	4	+ Read Current −	
Relay NI9485, slot4, pin0, Relay NI9485, slot4, pin1,	5	+ On/Off Signal −	
AO NI9264, slot2, pin3, AO2	6	+ Set Voltage −	Anode tube power supply
AI NI9205, slot1, pin3, AI2	7	+ Read Voltage −	
AO NI9264, slot2, pin4, AO3	8	+ Set Current −	
AI NI9205, slot1, pin4, AI3	9	+ Read Current −	
Relay NI9485, slot4, pin2, Relay NI9485, slot4, pin3,	10	+ On/Off Signal −	
AO NI9264, slot2, pin5, AO4	11	+ Set Voltage −	Inner barrier supply
AI NI9205, slot1, pin5, AI4	12	+ Read Voltage −	
AO NI9264, slot2, pin6, AO5	13	+ Set Current −	
AI NI9205, slot1, pin6, AI5	14	+ Read Current −	
Relay NI9485, slot4, pin4, Relay NI9485, slot4, pin5,	15	+ On/Off Signal −	


AO NI9264, slot2, pin7, AO6
16
Set Voltage
Extractor,
EBIS platform config.
AI NI9205, slot1, pin7, AI6
17
Read Voltage
AO NI9264, slot2, pin8, AO7
18
Set Current
AI NI9205, slot1, pin8, AI7
19
Read Current
Relay NI9485, slot4, pin6,
Relay NI9485, slot4, pin7,
20
On/Off Signal
AO NI9264, slot2, pin11, AO8
21
Set Voltage
Spare
supply
AI NI9205, slot1, pin20, AI8
22
Read Voltage
AO NI9264, slot2, pin12, AO9
23
Set Current
AI NI9205, slot1, pin21, AI9
24
Read Current
Relay NI9485, slot4, pin8,
Relay NI9485, slot4, pin9,
25
On/Off Signal
AO NI9264, slot2, pin13, AO10
26
Set Voltage
Trap
supply A
AI NI9205, slot1, pin22, AI10
27
Read Voltage
AO NI9264, slot2, pin14, AO11
28
Set Current
AI NI9205, slot1, pin23, AI11
29
Read Current
Relay NI9485, slot4, pin10,
Relay NI9485, slot4, pin11,
30
On/Off Signal
AO NI9264, slot2, pin15, AO12
31
Set Voltage
Trap
supply B
AI NI9205, slot1, pin24, AI12
32
Read Voltage
AO NI9264, slot2, pin16, AO13
33
Set Current
AI NI9205, slot1, pin25, AI13
34
Read Current
Relay NI9485, slot4, pin12,
Relay NI9485, slot4, pin13,
35
On/Off Signal
+
–


AO NI9264, slot2, pin11, AO14
AI NI9205, slot1, pin26, AI14
AO NI9264, slot2, pin12, AO15
AI NI9205, slot1, pin27, AI15
Relay NI9485, slot4, pin14,
Relay NI9485, slot4, pin15,
AO NI9264, slot3, pin1, AO0
AI NI9205, slot1, pin11, AI16
AO NI9264, slot3, pin2, AO1
AI NI9205, slot1, pin12, AI17
Relay NI9485, slot5, pin0,
Relay NI9485, slot5, pin1,
AO NI9264, slot3, pin3, AO2
AI NI9205, slot1, pin13, AI18
AO NI9264, slot3, pin4, AO3
AI NI9205, slot1, pin14, AI19
Relay NI9485, slot5, pin2,
Relay NI9485, slot5, pin3,
AO NI9264, slot3, pin5, AO4
AI NI9205, slot1, pin15, AI20
AO NI9264, slot3, pin6, AO5
AI NI9205, slot1, pin16, AI21
Relay NI9485, slot5, pin4,
Relay NI9485, slot5, pin5,
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
Set Voltage
Read Voltage
Set Current
Read Current
On/Off Signal
Outer
barrier supply A
Outer
barrier supply B
Outer Drift tube Supply A
Outer Drift tube Supply B
+
–


AO NI9264, slot3, pin7, AO6
AI NI9205, slot1, pin17, AI22
AO NI9264, slot3, pin8, AO7
AI NI9205, slot1, pin18, AI23
Relay NI9485, slot5, pin6,
Relay NI9485, slot5, pin7,
AI NI9205, slot1, pin34, AI28
AI NI9205, slot1, pin35, AI29
Relay NI9485, slot5, pin10,
Relay NI9485, slot5, pin11,
Relay NI9485, slot5, pin12,
Relay NI9485, slot5, pin13,
56
57
58
59
60
61
62
63
64
+
Set Voltage
–
+
Read Voltage
–
+
Set Current
–
+
Read Current
–
+
On/Off Signal
–
RESERVE
PSU
Penning gauge gun
Penning gauge collector
TREK 1-4
Adaptor electrode On/Off

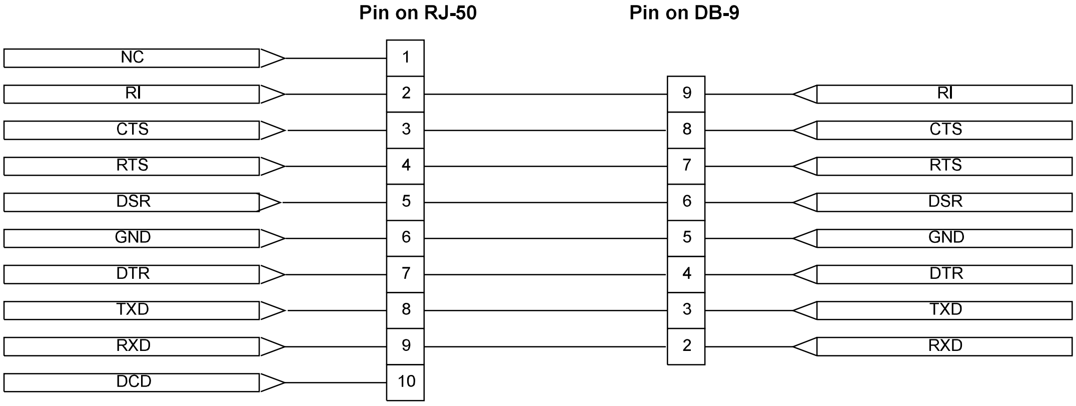
D-SUB 15 Connector on the backplane

Wires from patch HV cRIO DI slot6	**D-SUB Pin**	**D-SUB Connector**
⏚	1	Ground
DI NI9425, slot6, pin1, DI0	2	Spare 3
DI NI9425, slot6, pin2, DI1	3	Spare 1
DI NI9425, slot6, pin3, DI2	4	Water turbo
DI NI9425, slot6, pin4, DI3	5	Water bore
DI NI9425, slot6, pin5, DI4	6	Water collector
DI NI9425, slot6, pin6, DI5	7	Water gun
DI NI9425, slot6, pin7, DI6	8	Cathode heating interlock
DI NI9425, slot6, pin8, DI7	9	Spare 4
DI NI9425, slot6, pin11, DI8	10	Spare 2
DI NI9425, slot6, pin12, DI9	11	Relay from anode platform cage
DI NI9425, slot6, pin13, DI10	12	Relay Gun-platform from Door
DI NI9425, slot6, pin14, DI11	13	Relay from gun Pirani gauge
DI NI9425, slot6, pin15, DI12	14	Relay from gun Penning gauge
DI NI9425, slot6, pin15, DI12	15	Relay from collector Penning gauge

Serial-communication Extention from cRIO-Chassie to the backplane

The wiring from the RJ-45 to the D-SUB 9 connection on the backplane for RS-232 and RS-485.
They both use the same cable so the diagram counts for both.

RS-232 and RS-485
RJ-45 to D-SUB 9



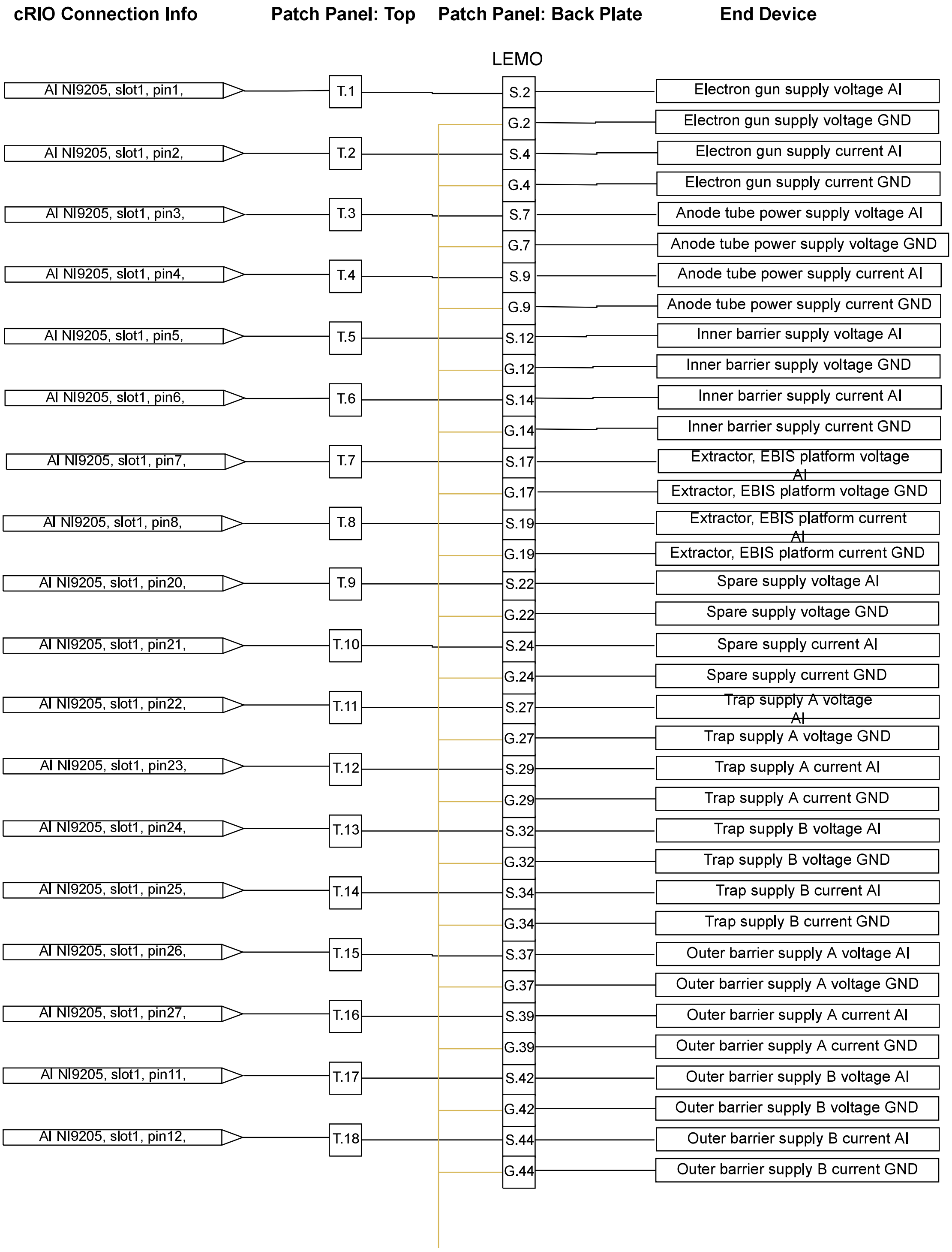
Connection diagram for the Top Screw Terminal

Information

Platform: vacuum water beam
Order: Screw terminal are in ascending order

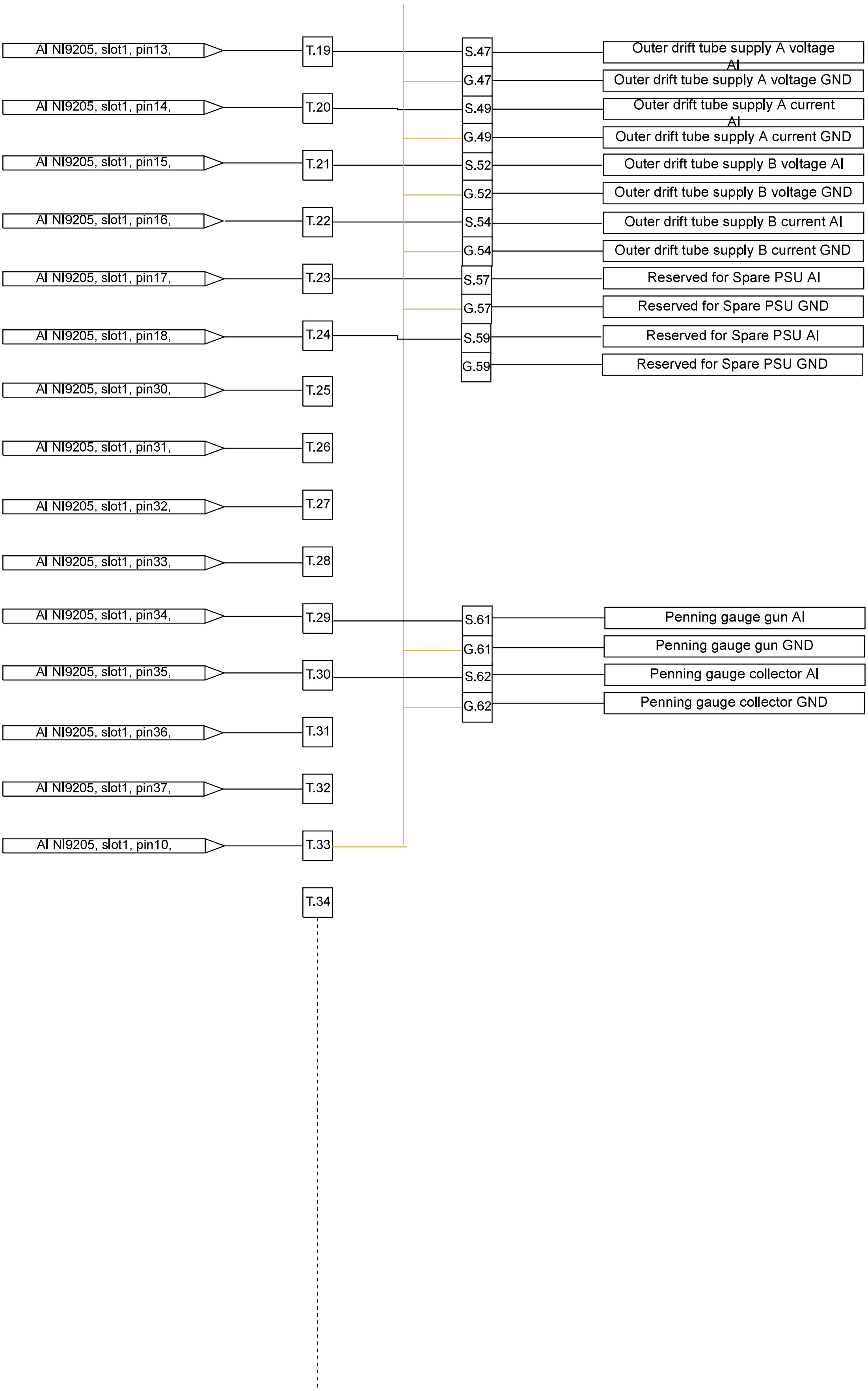
Definitions

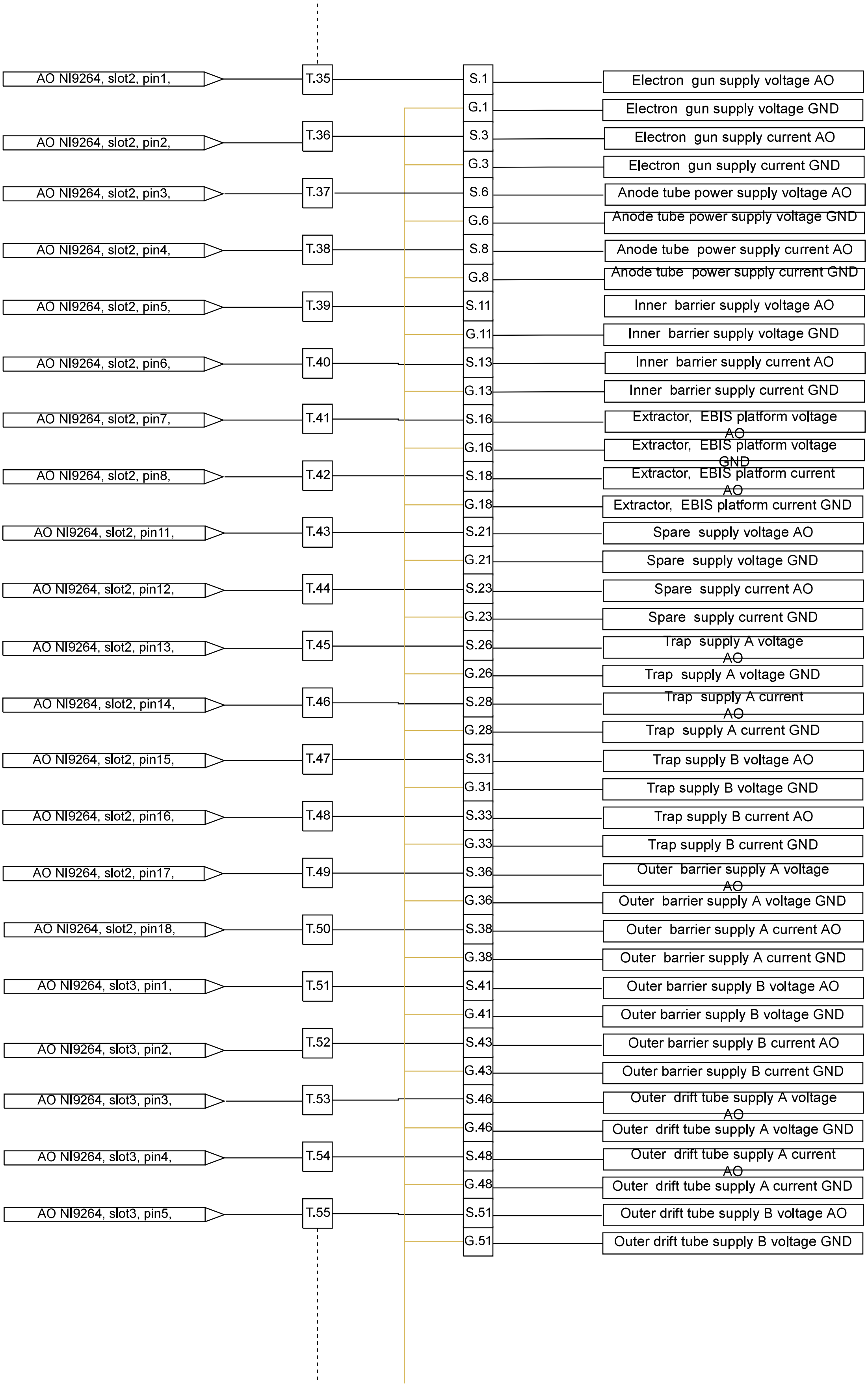
T.x = Top Screw Terminal
S.x = Signal from LEMO connector x
G.x = Ground from LEMO connector x
AI = Analog In
AO = Analog Out
GND = Ground

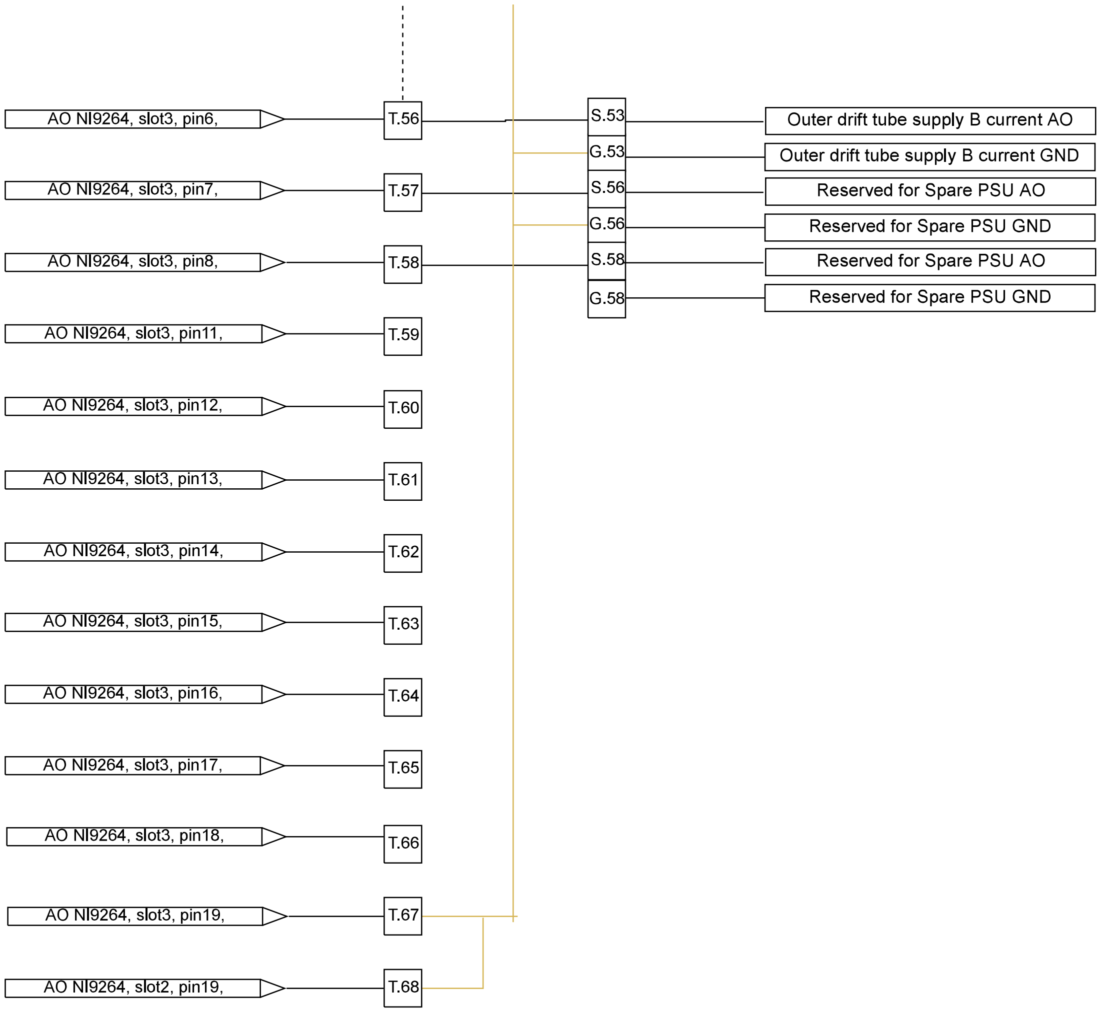


LEMO

cRIO Connection Info	Patch Panel: Top	Patch Panel: Back Plate	End Device
AI NI9205, slot1, pin1,	T.1	S.2	Electron gun supply voltage AI
		G.2	Electron gun supply voltage GND
AI NI9205, slot1, pin2,	T.2	S.4	Electron gun supply current AI
		G.4	Electron gun supply current GND
AI NI9205, slot1, pin3,	T.3	S.7	Anode tube power supply voltage AI
		G.7	Anode tube power supply voltage GND
AI NI9205, slot1, pin4,	T.4	S.9	Anode tube power supply current AI
		G.9	Anode tube power supply current GND
AI NI9205, slot1, pin5,	T.5	S.12	Inner barrier supply voltage AI
		G.12	Inner barrier supply voltage GND
AI NI9205, slot1, pin6,	T.6	S.14	Inner barrier supply current AI
		G.14	Inner barrier supply current GND
AI NI9205, slot1, pin7,	T.7	S.17	Extractor, EBIS platform voltage AI
		G.17	Extractor, EBIS platform voltage GND
AI NI9205, slot1, pin8,	T.8	S.19	Extractor, EBIS platform current AI
		G.19	Extractor, EBIS platform current GND
AI NI9205, slot1, pin20,	T.9	S.22	Spare supply voltage AI
		G.22	Spare supply voltage GND
AI NI9205, slot1, pin21,	T.10	S.24	Spare supply current AI
		G.24	Spare supply current GND
AI NI9205, slot1, pin22,	T.11	S.27	Trap supply A voltage AI
		G.27	Trap supply A voltage GND
AI NI9205, slot1, pin23,	T.12	S.29	Trap supply A current AI
		G.29	Trap supply A current GND
AI NI9205, slot1, pin24,	T.13	S.32	Trap supply B voltage AI
		G.32	Trap supply B voltage GND
AI NI9205, slot1, pin25,	T.14	S.34	Trap supply B current AI
		G.34	Trap supply B current GND
AI NI9205, slot1, pin26,	T.15	S.37	Outer barrier supply A voltage AI
		G.37	Outer barrier supply A voltage GND
AI NI9205, slot1, pin27,	T.16	S.39	Outer barrier supply A current AI
		G.39	Outer barrier supply A current GND
AI NI9205, slot1, pin11,	T.17	S.42	Outer barrier supply B voltage AI
		G.42	Outer barrier supply B voltage GND
AI NI9205, slot1, pin12,	T.18	S.44	Outer barrier supply B current AI
		G.44	Outer barrier supply B current GND


AI NI9205, slot1, pin13,
T.19
S.47
Outer drift tube supply A voltage AI
G.47
Outer drift tube supply A voltage GND
AI NI9205, slot1, pin14,
T.20
S.49
Outer drift tube supply A current AI
G.49
Outer drift tube supply A current GND
AI NI9205, slot1, pin15,
T.21
S.52
Outer drift tube supply B voltage AI
G.52
Outer drift tube supply B voltage GND
AI NI9205, slot1, pin16,
T.22
S.54
Outer drift tube supply B current AI
G.54
Outer drift tube supply B current GND
AI NI9205, slot1, pin17,
T.23
S.57
Reserved for Spare PSU AI
G.57
Reserved for Spare PSU GND
AI NI9205, slot1, pin18,
T.24
S.59
Reserved for Spare PSU AI
G.59
Reserved for Spare PSU GND
AI NI9205, slot1, pin30,
T.25
AI NI9205, slot1, pin31,
T.26
AI NI9205, slot1, pin32,
T.27
AI NI9205, slot1, pin33,
T.28
AI NI9205, slot1, pin34,
T.29
S.61
Penning gauge gun AI
G.61
Penning gauge gun GND
AI NI9205, slot1, pin35,
T.30
S.62
Penning gauge collector AI
G.62
Penning gauge collector GND
AI NI9205, slot1, pin36,
T.31
AI NI9205, slot1, pin37,
T.32
AI NI9205, slot1, pin10,
T.33
T.34


AO NI9264, slot2, pin1,
T.35
S.1
Electron gun supply voltage AO
G.1
Electron gun supply voltage GND
AO NI9264, slot2, pin2,
T.36
S.3
Electron gun supply current AO
G.3
Electron gun supply current GND
AO NI9264, slot2, pin3,
T.37
S.6
Anode tube power supply voltage AO
G.6
Anode tube power supply voltage GND
AO NI9264, slot2, pin4,
T.38
S.8
Anode tube power supply current AO
G.8
Anode tube power supply current GND
AO NI9264, slot2, pin5,
T.39
S.11
Inner barrier supply voltage AO
G.11
Inner barrier supply voltage GND
AO NI9264, slot2, pin6,
T.40
S.13
Inner barrier supply current AO
G.13
Inner barrier supply current GND
AO NI9264, slot2, pin7,
T.41
S.16
Extractor, EBIS platform voltage AO
G.16
Extractor, EBIS platform voltage GND
AO NI9264, slot2, pin8,
T.42
S.18
Extractor, EBIS platform current AO
G.18
Extractor, EBIS platform current GND
AO NI9264, slot2, pin11,
T.43
S.21
Spare supply voltage AO
G.21
Spare supply voltage GND
AO NI9264, slot2, pin12,
T.44
S.23
Spare supply current AO
G.23
Spare supply current GND
AO NI9264, slot2, pin13,
T.45
S.26
Trap supply A voltage AO
G.26
Trap supply A voltage GND
AO NI9264, slot2, pin14,
T.46
S.28
Trap supply A current AO
G.28
Trap supply A current GND
AO NI9264, slot2, pin15,
T.47
S.31
Trap supply B voltage AO
G.31
Trap supply B voltage GND
AO NI9264, slot2, pin16,
T.48
S.33
Trap supply B current AO
G.33
Trap supply B current GND
AO NI9264, slot2, pin17,
T.49
S.36
Outer barrier supply A voltage AO
G.36
Outer barrier supply A voltage GND
AO NI9264, slot2, pin18,
T.50
S.38
Outer barrier supply A current AO
G.38
Outer barrier supply A current GND
AO NI9264, slot3, pin1,
T.51
S.41
Outer barrier supply B voltage AO
G.41
Outer barrier supply B voltage GND
AO NI9264, slot3, pin2,
T.52
S.43
Outer barrier supply B current AO
G.43
Outer barrier supply B current GND
AO NI9264, slot3, pin3,
T.53
S.46
Outer drift tube supply A voltage AO
G.46
Outer drift tube supply A voltage GND
AO NI9264, slot3, pin4,
T.54
S.48
Outer drift tube supply A current AO
G.48
Outer drift tube supply A current GND
AO NI9264, slot3, pin5,
T.55
S.51
Outer drift tube supply B voltage AO
G.51
Outer drift tube supply B voltage GND


AO NI9264, slot3, pin6,
T.56
S.53
Outer drift tube supply B current AO
G.53
Outer drift tube supply B current GND
AO NI9264, slot3, pin7,
T.57
S.56
Reserved for Spare PSU AO
G.56
Reserved for Spare PSU GND
AO NI9264, slot3, pin8,
T.58
S.58
Reserved for Spare PSU AO
G.58
Reserved for Spare PSU GND
AO NI9264, slot3, pin11,
T.59
AO NI9264, slot3, pin12,
T.60
AO NI9264, slot3, pin13,
T.61
AO NI9264, slot3, pin14,
T.62
AO NI9264, slot3, pin15,
T.63
AO NI9264, slot3, pin16,
T.64
AO NI9264, slot3, pin17,
T.65
AO NI9264, slot3, pin18,
T.66
AO NI9264, slot3, pin19,
T.67
AO NI9264, slot2, pin19,
T.68

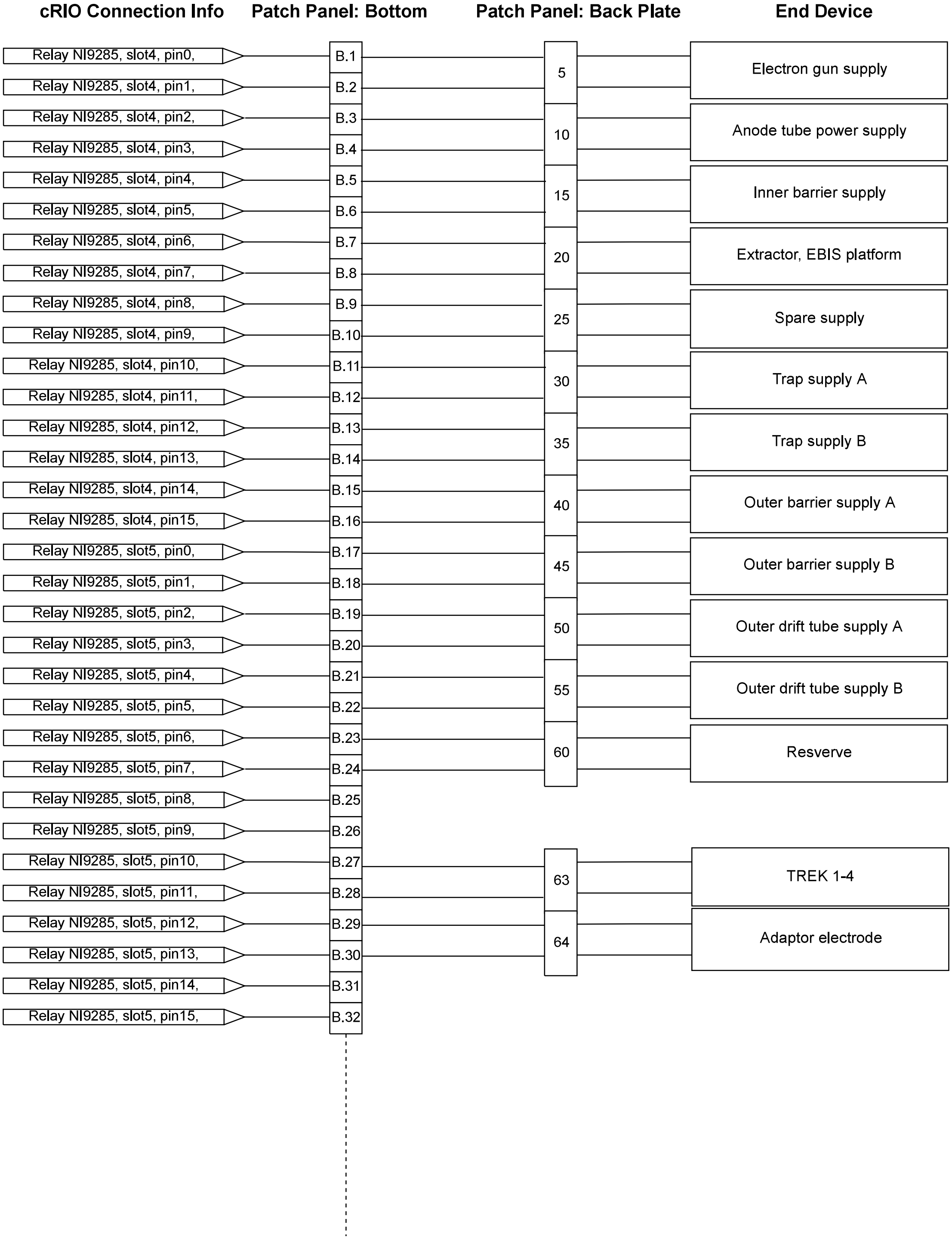
Connection diagram for the Bottom Screw Terminal

Information

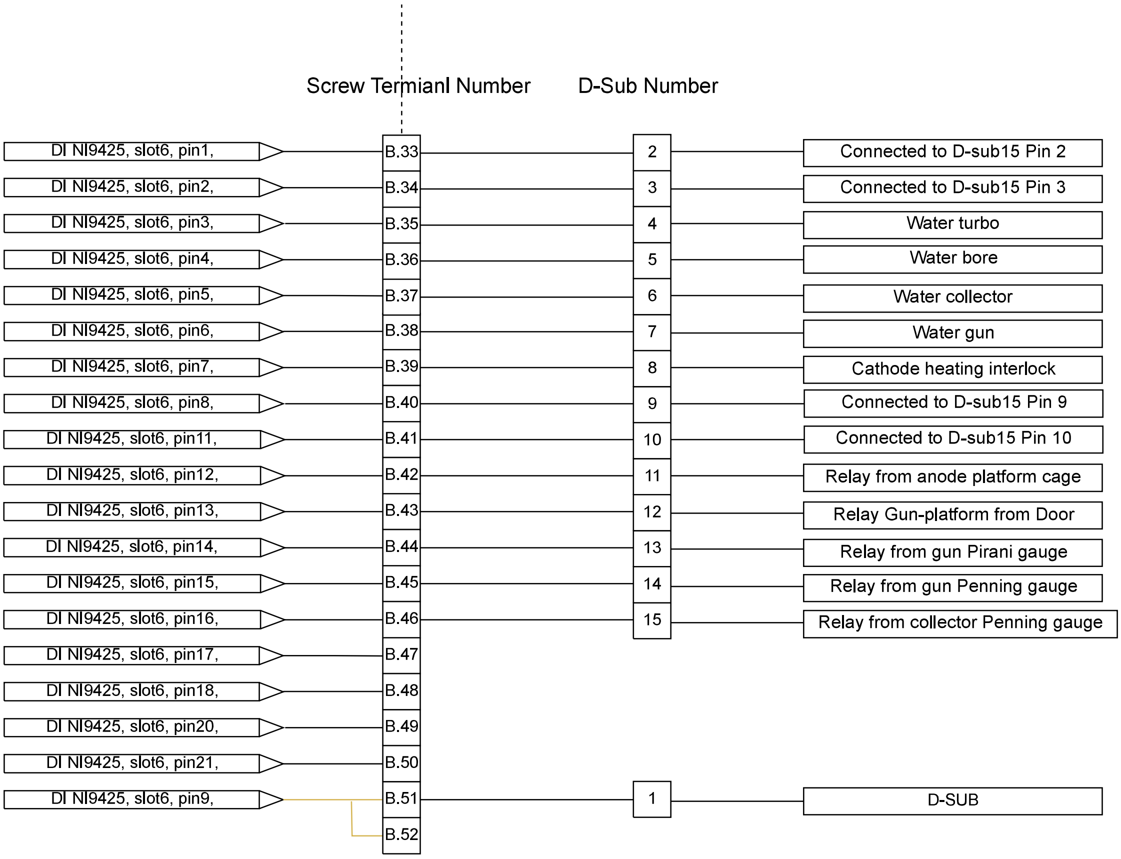
cRIO: Vacuum&Water, and Beam diagnostic
Order: Screw terminal are in ascending order

Definitions

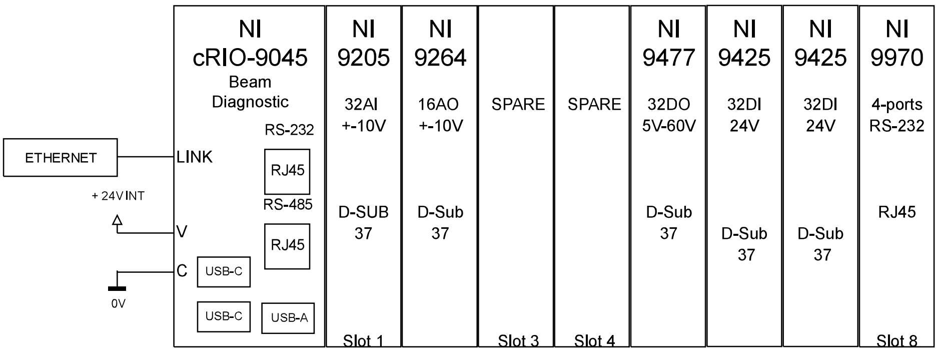
B.x = Top Screw Terminal
GND = Ground
xx-x = Berndi_connector-berndie_pin



cRIO Connection Info	Patch Panel: Bottom	Patch Panel: Back Plate	End Device
Relay NI9285, slot4, pin0,	B.1	5	Electron gun supply
Relay NI9285, slot4, pin1,	B.2		
Relay NI9285, slot4, pin2,	B.3	10	Anode tube power supply
Relay NI9285, slot4, pin3,	B.4		
Relay NI9285, slot4, pin4,	B.5	15	Inner barrier supply
Relay NI9285, slot4, pin5,	B.6		
Relay NI9285, slot4, pin6,	B.7	20	Extractor, EBIS platform
Relay NI9285, slot4, pin7,	B.8		
Relay NI9285, slot4, pin8,	B.9	25	Spare supply
Relay NI9285, slot4, pin9,	B.10		
Relay NI9285, slot4, pin10,	B.11	30	Trap supply A
Relay NI9285, slot4, pin11,	B.12		
Relay NI9285, slot4, pin12,	B.13	35	Trap supply B
Relay NI9285, slot4, pin13,	B.14		
Relay NI9285, slot4, pin14,	B.15	40	Outer barrier supply A
Relay NI9285, slot4, pin15,	B.16		
Relay NI9285, slot5, pin0,	B.17	45	Outer barrier supply B
Relay NI9285, slot5, pin1,	B.18		
Relay NI9285, slot5, pin2,	B.19	50	Outer drift tube supply A
Relay NI9285, slot5, pin3,	B.20		
Relay NI9285, slot5, pin4,	B.21	55	Outer drift tube supply B
Relay NI9285, slot5, pin5,	B.22		
Relay NI9285, slot5, pin6,	B.23	60	Resverve
Relay NI9285, slot5, pin7,	B.24		
Relay NI9285, slot5, pin8,	B.25		
Relay NI9285, slot5, pin9,	B.26		
Relay NI9285, slot5, pin10,	B.27	63	TREK 1-4
Relay NI9285, slot5, pin11,	B.28		
Relay NI9285, slot5, pin12,	B.29	64	Adaptor electrode
Relay NI9285, slot5, pin13,	B.30		
Relay NI9285, slot5, pin14,	B.31		
Relay NI9285, slot5, pin15,	B.32		


Screw TermianI Number
D-Sub Number
DI NI9425, slot6, pin1, B.33 2 Connected to D-sub15 Pin 2
DI NI9425, slot6, pin2, B.34 3 Connected to D-sub15 Pin 3
DI NI9425, slot6, pin3, B.35 4 Water turbo
DI NI9425, slot6, pin4, B.36 5 Water bore
DI NI9425, slot6, pin5, B.37 6 Water collector
DI NI9425, slot6, pin6, B.38 7 Water gun
DI NI9425, slot6, pin7, B.39 8 Cathode heating interlock
DI NI9425, slot6, pin8, B.40 9 Connected to D-sub15 Pin 9
DI NI9425, slot6, pin11, B.41 10 Connected to D-sub15 Pin 10
DI NI9425, slot6, pin12, B.42 11 Relay from anode platform cage
DI NI9425, slot6, pin13, B.43 12 Relay Gun-platform from Door
DI NI9425, slot6, pin14, B.44 13 Relay from gun Pirani gauge
DI NI9425, slot6, pin15, B.45 14 Relay from gun Penning gauge
DI NI9425, slot6, pin16, B.46 15 Relay from collector Penning gauge
DI NI9425, slot6, pin17, B.47
DI NI9425, slot6, pin18, B.48
DI NI9425, slot6, pin20, B.49
DI NI9425, slot6, pin21, B.50
DI NI9425, slot6, pin9, B.51 1 D-SUB
B.52

cRIO Module setup and connection



TwinEBIS	ECHELLE SCALE	SH-CERN	NOM/NAME	DATE
cRIO Beam Diagnostic & Vacuum		APPRO.		
		CONTROL		
		DES/DRA.	*Steen*	2019-05-03
		REMPLACE/REPLACES		
CERN				IND.

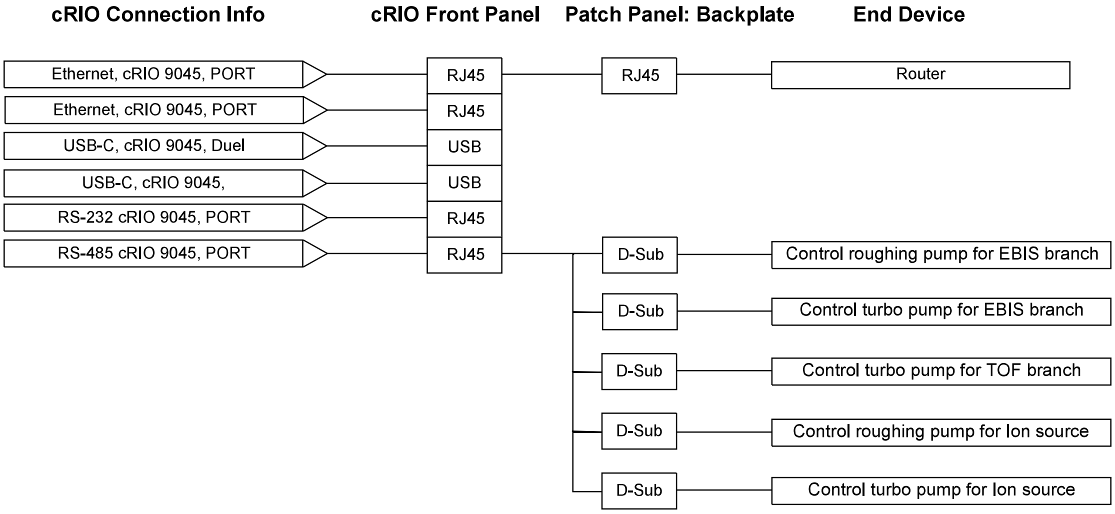
Connection Diagram for the cRIO Front Panel

Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: cRIO Front panel

Definitions

D-Sub X = D-sub connector



Connection Diagram for the Analog Input Module

Information

cRIO: Beam diagnostic and Vacuum
Perspective: Analog Inputs are in ascending order

Definitions

T.x = Top Screw Terminal

cRIO Connection Info	Patch Panel: Top	End Device
AI NI9205, slot1, pin1,	T.1	EBIS Branch MCP voltage
AI NI9205, slot1, pin2,	T.2	EBIS Branch MCP current
AI NI9205, slot1, pin3,	T.3	EBIS Branch Phosphor screen voltage
AI NI9205, slot1, pin4,	T.4	EBIS Branch Phosphor screen current
AI NI9205, slot1, pin5,	T.5	TOF Branch MCP
AI NI9205, slot1, pin6,	T.6	TOF Branch MCP current
AI NI9205, slot1, pin7,	T.7	TOF branch channeltron voltage
AI NI9205, slot1, pin8,	T.8	TOF branch channeltron Current
AI NI9205, slot1, pin20,	T.9	Reserved
AI NI9205, slot1, pin21,	T.10	Penning gauge EBIS branch
AI NI9205, slot1, pin22,	T.11	Pirani gauge EBIS branch
AI NI9205, slot1, pin23,	T.12	Penning gauge RFQ branch
AI NI9205, slot1, pin24,	T.13	Pirani gauge RFQ branch
AI NI9205, slot1, pin25,	T.14	Penning gauge TOF branch
AI NI9205, slot1, pin26,	T.15	Pirani gauge TOF branch
AI NI9205, slot1, pin27,	T.16	Penning gauge ion source branch
AI NI9205, slot1, pin11,	T.17	Pirani gauge ion source branch
AI NI9205, slot1, pin12,	T.18	Reserved AI
AI NI9205, slot1, pin13,	T.19	Reserved AI
AI NI9205, slot1, pin14,	T.20	
AI NI9205, slot1, pin15,	T.21	
AI NI9205, slot1, pin16,	T.22	
AI NI9205, slot1, pin17,	T.23	
AI NI9205, slot1, pin18,	T.24	
AI NI9205, slot1, pin30,	T.25	
AI NI9205, slot1, pin31,	T.26	
AI NI9205, slot1, pin32,	T.27	
AI NI9205, slot1, pin33,	T.28	
AI NI9205, slot1, pin34,	T.29	
AI NI9205, slot1, pin35,	T.30	
AI NI9205, slot1, pin36,	T.31	
AI NI9205, slot1, pin37,	T.32	
AI NI9205, slot1, pin9,	NC	
AI NI9205, slot1, pin10,	NC	
AI NI9205, slot1, pin28,	NC	
AI NI9205, slot1, pin29,	T.33	
AI NI9205, slot1, pin19,	T.34	Common Analog In Ground

Connection Diagram for the Analog Output Module

Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Analog Outputs are in ascending order

Definitions

T.x = Top Screw Terminal

cRIO Connection Info	Patch Panel: Top	End Device
AO NI9264, slot2, pin1,	T.36	EBIS Branch MCP voltage
AO NI9264, slot2, pin2,	T.37	EBIS Branch MCP current
AO NI9264, slot2, pin3,	T.38	EBIS Branch Phosphor screen voltage
AO NI9264, slot2, pin4,	T.39	EBIS Branch Phosphor screen current
AO NI9264, slot2, pin5,	T.40	TOF Branch MCP
AO NI9264, slot2, pin6,	T.41	TOF Branch MCP current
AO NI9264, slot2, pin7,	T.42	TOF branch channeltron voltage
AO NI9264, slot2, pin8,	T.43	TOF branch channeltron Current
AO NI9264, slot2, pin11,	T.44	Reserve voltage
AO NI9264, slot2, pin12,	T.45	EBIS Branch FC Supressor voltage
AO NI9264, slot2, pin13,	T.46	RFQ Branch FC Supressor voltage
AO NI9264, slot2, pin14,	T.47	ION Branch FC Supressor voltage
AO NI9264, slot2, pin15,	T.48	Reserve voltage
AO NI9264, slot2, pin16,	T.49	
AO NI9264, slot2, pin17,	T.50	
AO NI9264, slot2, pin18,	T.51	
AO NI9264, slot2, pin19,	T.52	Analog Out Common Ground
AO NI9264, slot2, pin20,	NC	
AO NI9264, slot2, pin21,	NC	
AO NI9264, slot2, pin22,	NC	
AO NI9264, slot2, pin23,	NC	
AO NI9264, slot2, pin24,	NC	
AO NI9264, slot2, pin25,	NC	
AO NI9264, slot2, pin26,	NC	
AO NI9264, slot2, pin27,	NC	
AO NI9264, slot2, pin30,	NC	
AO NI9264, slot2, pin31,	NC	
AO NI9264, slot2, pin32,	NC	
AO NI9264, slot2, pin33,	NC	
AO NI9264, slot2, pin34,	NC	
AO NI9264, slot2, pin35,	NC	
AO NI9264, slot2, pin36,	NC	
AO NI9264, slot2, pin37,	NC	
AO NI9264, slot2, pin9,	NC	
AO NI9264, slot2, pin10,	NC	
AO NI9264, slot2, pin28,	NC	
AO NI9264, slot2, pin29,	NC	

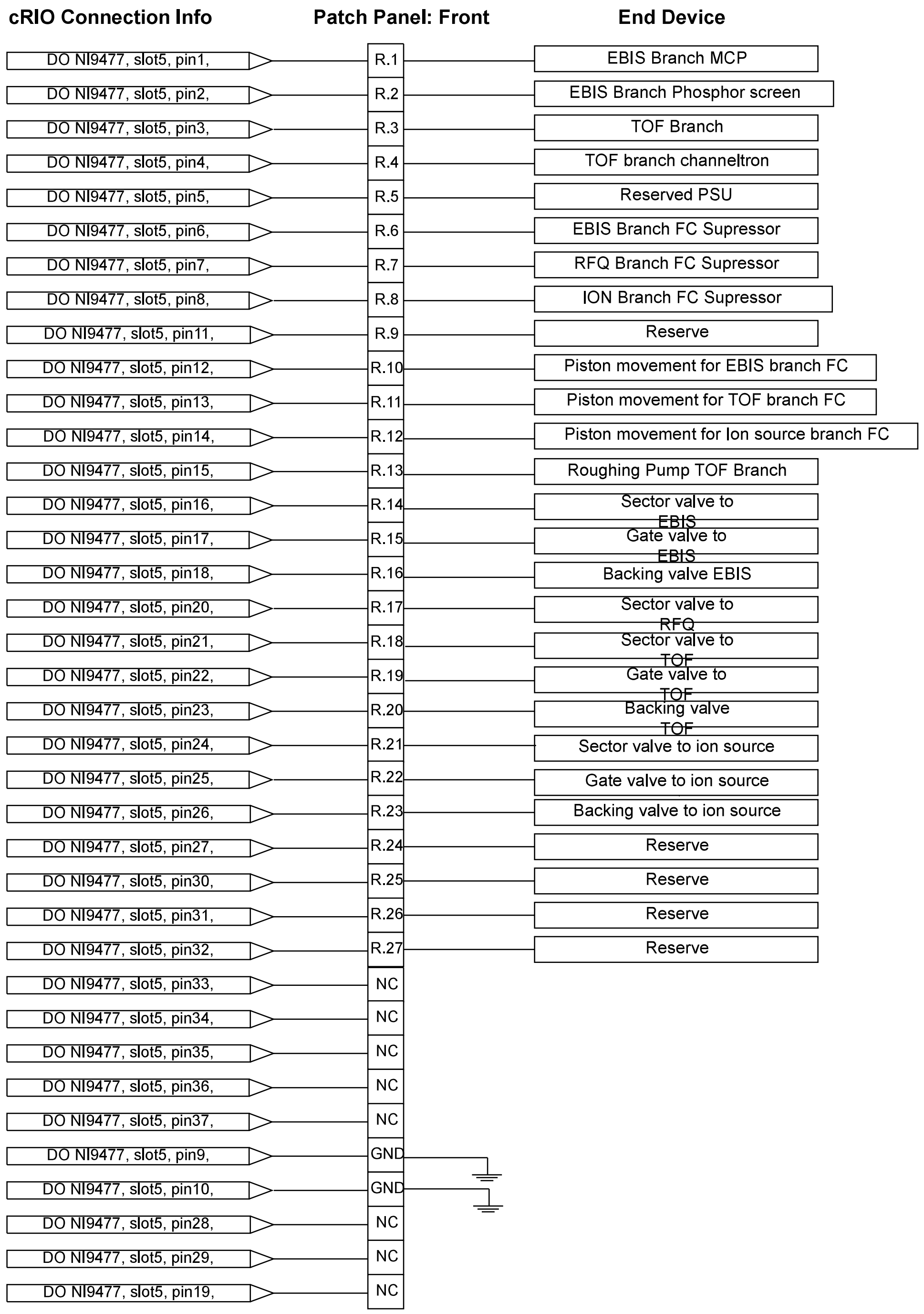
Connection Diagram for the Digital Output Module

Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Digital Output are in ascending order

Definitions

F.x = Front Screw Terminal
R.x = Relay terminal

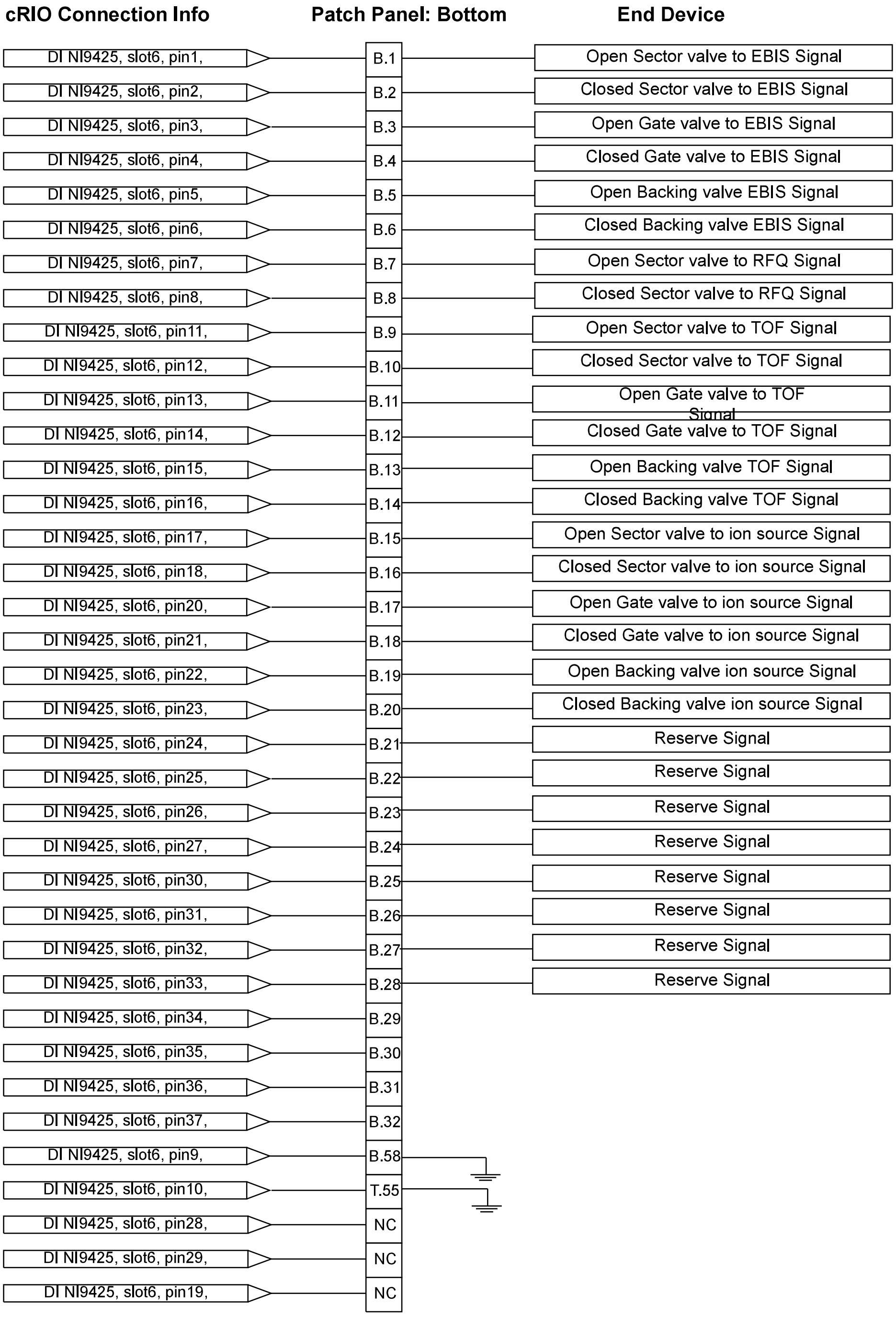


cRIO Connection Info	Patch Panel: Front	End Device
DO NI9477, slot5, pin1,	R.1	EBIS Branch MCP
DO NI9477, slot5, pin2,	R.2	EBIS Branch Phosphor screen
DO NI9477, slot5, pin3,	R.3	TOF Branch
DO NI9477, slot5, pin4,	R.4	TOF branch channeltron
DO NI9477, slot5, pin5,	R.5	Reserved PSU
DO NI9477, slot5, pin6,	R.6	EBIS Branch FC Supressor
DO NI9477, slot5, pin7,	R.7	RFQ Branch FC Supressor
DO NI9477, slot5, pin8,	R.8	ION Branch FC Supressor
DO NI9477, slot5, pin11,	R.9	Reserve
DO NI9477, slot5, pin12,	R.10	Piston movement for EBIS branch FC
DO NI9477, slot5, pin13,	R.11	Piston movement for TOF branch FC
DO NI9477, slot5, pin14,	R.12	Piston movement for Ion source branch FC
DO NI9477, slot5, pin15,	R.13	Roughing Pump TOF Branch
DO NI9477, slot5, pin16,	R.14	Sector valve to EBIS
DO NI9477, slot5, pin17,	R.15	Gate valve to EBIS
DO NI9477, slot5, pin18,	R.16	Backing valve EBIS
DO NI9477, slot5, pin20,	R.17	Sector valve to RFQ
DO NI9477, slot5, pin21,	R.18	Sector valve to TOF
DO NI9477, slot5, pin22,	R.19	Gate valve to TOF
DO NI9477, slot5, pin23,	R.20	Backing valve TOF
DO NI9477, slot5, pin24,	R.21	Sector valve to ion source
DO NI9477, slot5, pin25,	R.22	Gate valve to ion source
DO NI9477, slot5, pin26,	R.23	Backing valve to ion source
DO NI9477, slot5, pin27,	R.24	Reserve
DO NI9477, slot5, pin30,	R.25	Reserve
DO NI9477, slot5, pin31,	R.26	Reserve
DO NI9477, slot5, pin32,	R.27	Reserve
DO NI9477, slot5, pin33,	NC	
DO NI9477, slot5, pin34,	NC	
DO NI9477, slot5, pin35,	NC	
DO NI9477, slot5, pin36,	NC	
DO NI9477, slot5, pin37,	NC	
DO NI9477, slot5, pin9,	GND	
DO NI9477, slot5, pin10,	GND	
DO NI9477, slot5, pin28,	NC	
DO NI9477, slot5, pin29,	NC	
DO NI9477, slot5, pin19,	NC	

Connection Diagram for the Digital Input 1 Module

Information
cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Digital input are in ascending order

Definitions
T.x = Top Screw Terminal
B.x = Bottom Screw Terminal



cRIO Connection Info	Patch Panel: Bottom	End Device
DI NI9425, slot6, pin1,	B.1	Open Sector valve to EBIS Signal
DI NI9425, slot6, pin2,	B.2	Closed Sector valve to EBIS Signal
DI NI9425, slot6, pin3,	B.3	Open Gate valve to EBIS Signal
DI NI9425, slot6, pin4,	B.4	Closed Gate valve to EBIS Signal
DI NI9425, slot6, pin5,	B.5	Open Backing valve EBIS Signal
DI NI9425, slot6, pin6,	B.6	Closed Backing valve EBIS Signal
DI NI9425, slot6, pin7,	B.7	Open Sector valve to RFQ Signal
DI NI9425, slot6, pin8,	B.8	Closed Sector valve to RFQ Signal
DI NI9425, slot6, pin11,	B.9	Open Sector valve to TOF Signal
DI NI9425, slot6, pin12,	B.10	Closed Sector valve to TOF Signal
DI NI9425, slot6, pin13,	B.11	Open Gate valve to TOF Signal
DI NI9425, slot6, pin14,	B.12	Closed Gate valve to TOF Signal
DI NI9425, slot6, pin15,	B.13	Open Backing valve TOF Signal
DI NI9425, slot6, pin16,	B.14	Closed Backing valve TOF Signal
DI NI9425, slot6, pin17,	B.15	Open Sector valve to ion source Signal
DI NI9425, slot6, pin18,	B.16	Closed Sector valve to ion source Signal
DI NI9425, slot6, pin20,	B.17	Open Gate valve to ion source Signal
DI NI9425, slot6, pin21,	B.18	Closed Gate valve to ion source Signal
DI NI9425, slot6, pin22,	B.19	Open Backing valve ion source Signal
DI NI9425, slot6, pin23,	B.20	Closed Backing valve ion source Signal
DI NI9425, slot6, pin24,	B.21	Reserve Signal
DI NI9425, slot6, pin25,	B.22	Reserve Signal
DI NI9425, slot6, pin26,	B.23	Reserve Signal
DI NI9425, slot6, pin27,	B.24	Reserve Signal
DI NI9425, slot6, pin30,	B.25	Reserve Signal
DI NI9425, slot6, pin31,	B.26	Reserve Signal
DI NI9425, slot6, pin32,	B.27	Reserve Signal
DI NI9425, slot6, pin33,	B.28	Reserve Signal
DI NI9425, slot6, pin34,	B.29	
DI NI9425, slot6, pin35,	B.30	
DI NI9425, slot6, pin36,	B.31	
DI NI9425, slot6, pin37,	B.32	
DI NI9425, slot6, pin9,	B.58	
DI NI9425, slot6, pin10,	T.55	
DI NI9425, slot6, pin28,	NC	
DI NI9425, slot6, pin29,	NC	
DI NI9425, slot6, pin19,	NC	

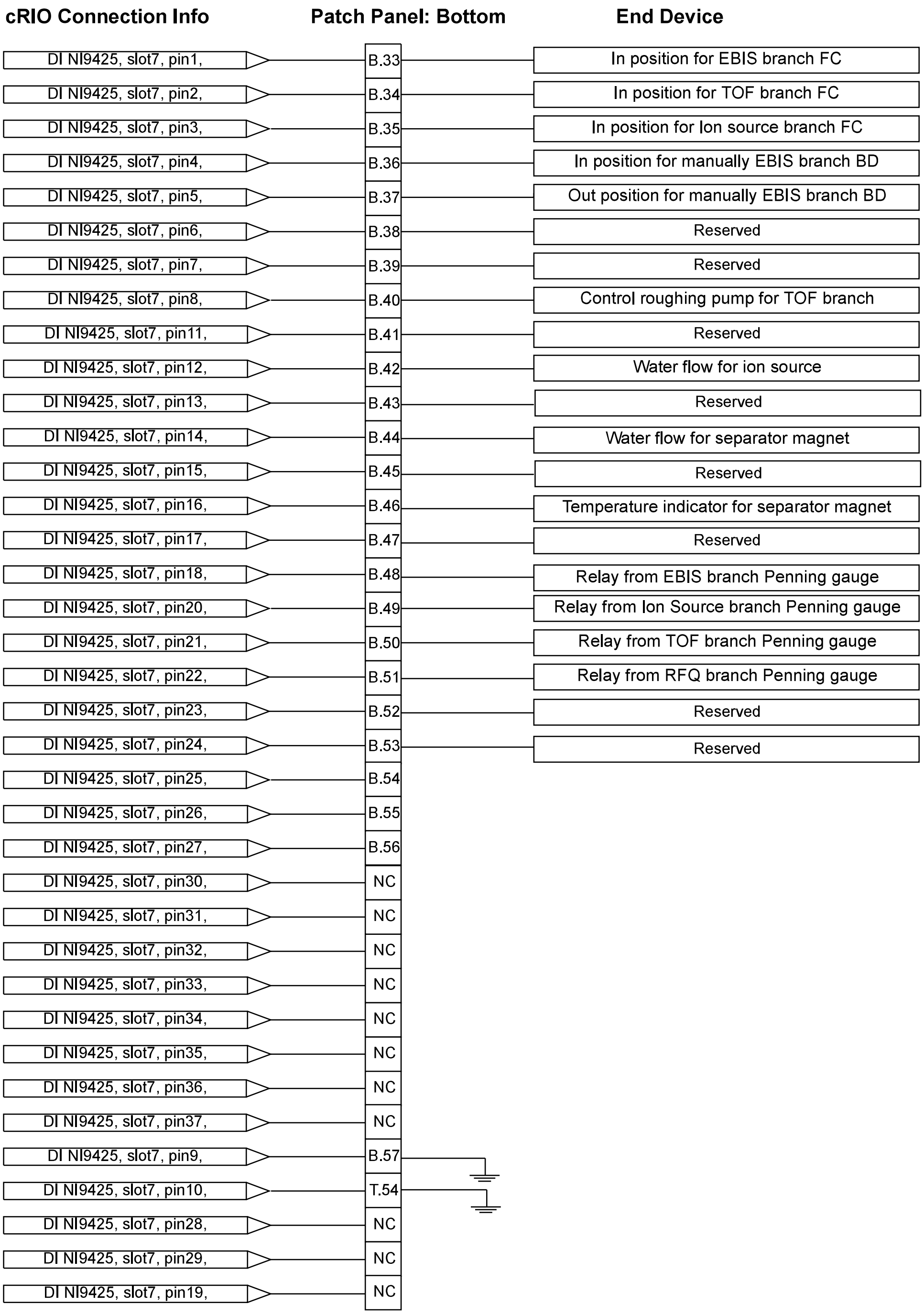
Connection Diagram for the Digital Input 2 Module

Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Digital Input are in ascending order

Definitions

T.x = Top Screw Terminal
B.x = Bottom Screw Terminal



cRIO Connection Info	Patch Panel: Bottom	End Device
DI NI9425, slot7, pin1,	B.33	In position for EBIS branch FC
DI NI9425, slot7, pin2,	B.34	In position for TOF branch FC
DI NI9425, slot7, pin3,	B.35	In position for Ion source branch FC
DI NI9425, slot7, pin4,	B.36	In position for manually EBIS branch BD
DI NI9425, slot7, pin5,	B.37	Out position for manually EBIS branch BD
DI NI9425, slot7, pin6,	B.38	Reserved
DI NI9425, slot7, pin7,	B.39	Reserved
DI NI9425, slot7, pin8,	B.40	Control roughing pump for TOF branch
DI NI9425, slot7, pin11,	B.41	Reserved
DI NI9425, slot7, pin12,	B.42	Water flow for ion source
DI NI9425, slot7, pin13,	B.43	Reserved
DI NI9425, slot7, pin14,	B.44	Water flow for separator magnet
DI NI9425, slot7, pin15,	B.45	Reserved
DI NI9425, slot7, pin16,	B.46	Temperature indicator for separator magnet
DI NI9425, slot7, pin17,	B.47	Reserved
DI NI9425, slot7, pin18,	B.48	Relay from EBIS branch Penning gauge
DI NI9425, slot7, pin20,	B.49	Relay from Ion Source branch Penning gauge
DI NI9425, slot7, pin21,	B.50	Relay from TOF branch Penning gauge
DI NI9425, slot7, pin22,	B.51	Relay from RFQ branch Penning gauge
DI NI9425, slot7, pin23,	B.52	Reserved
DI NI9425, slot7, pin24,	B.53	Reserved
DI NI9425, slot7, pin25,	B.54	
DI NI9425, slot7, pin26,	B.55	
DI NI9425, slot7, pin27,	B.56	
DI NI9425, slot7, pin30,	NC	
DI NI9425, slot7, pin31,	NC	
DI NI9425, slot7, pin32,	NC	
DI NI9425, slot7, pin33,	NC	
DI NI9425, slot7, pin34,	NC	
DI NI9425, slot7, pin35,	NC	
DI NI9425, slot7, pin36,	NC	
DI NI9425, slot7, pin37,	NC	
DI NI9425, slot7, pin9,	B.57	⏚
DI NI9425, slot7, pin10,	T.54	⏚
DI NI9425, slot7, pin28,	NC	
DI NI9425, slot7, pin29,	NC	
DI NI9425, slot7, pin19,	NC	

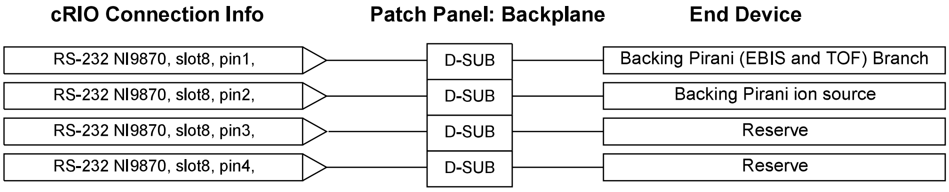
Connection Diagram from the RS-232 Module Perspective

Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Ports are in ascending order

Definitions

D-Sub X = D-sub connector



cRIO Connection Info	Patch Panel: Backplane	End Device
RS-232 NI9870, slot8, pin1,	D-SUB	Backing Pirani (EBIS and TOF) Branch
RS-232 NI9870, slot8, pin2,	D-SUB	Backing Pirani ion source
RS-232 NI9870, slot8, pin3,	D-SUB	Reserve
RS-232 NI9870, slot8, pin4,	D-SUB	Reserve

Connection Diagram for the backplane of the box

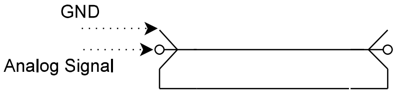
Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Back panel Connectors are in ascending order

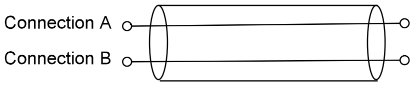
Definitions

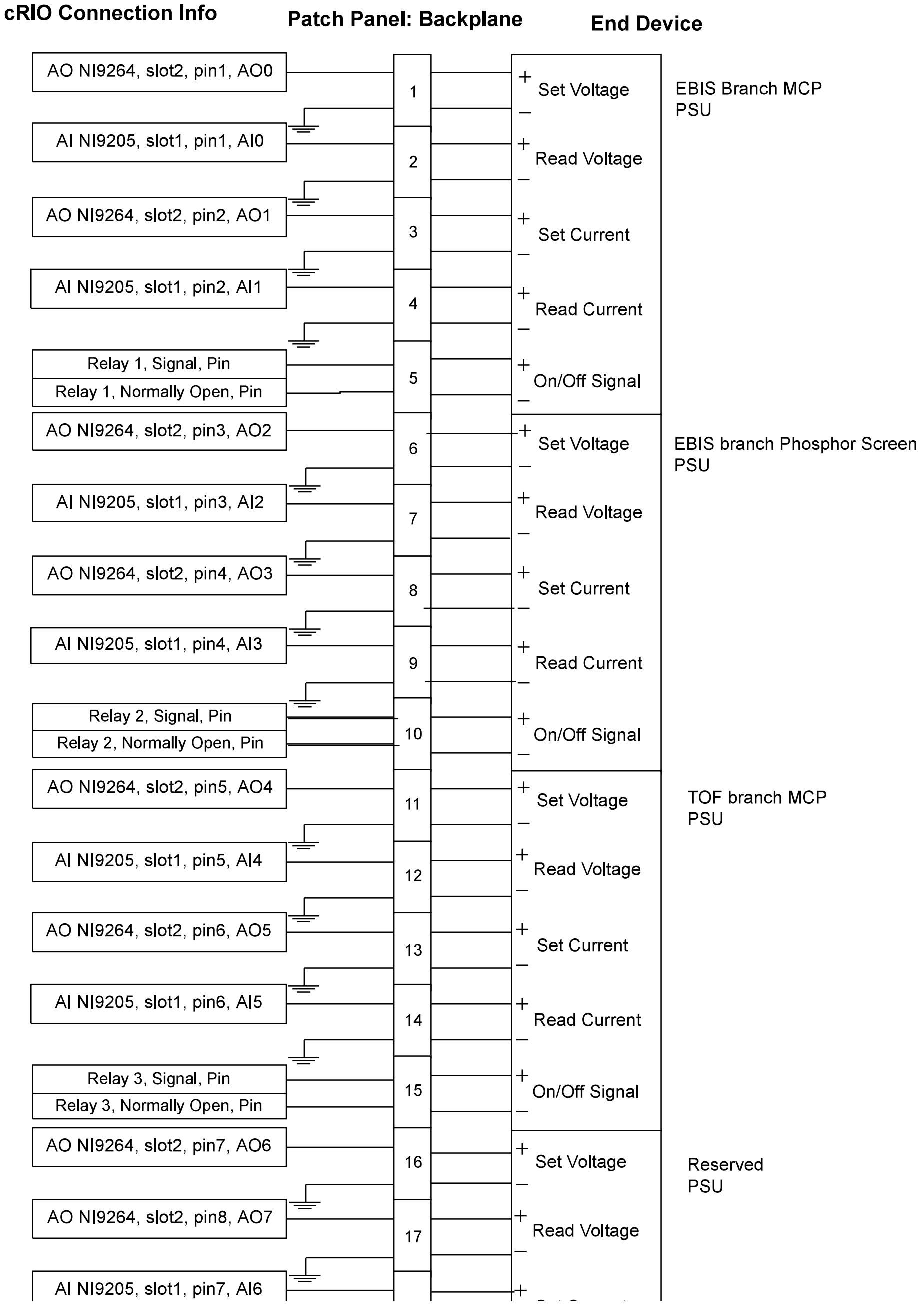
B.x = Top Screw Terminal
GND = Ground
xx-x = Berndi_connector-berndie_pin

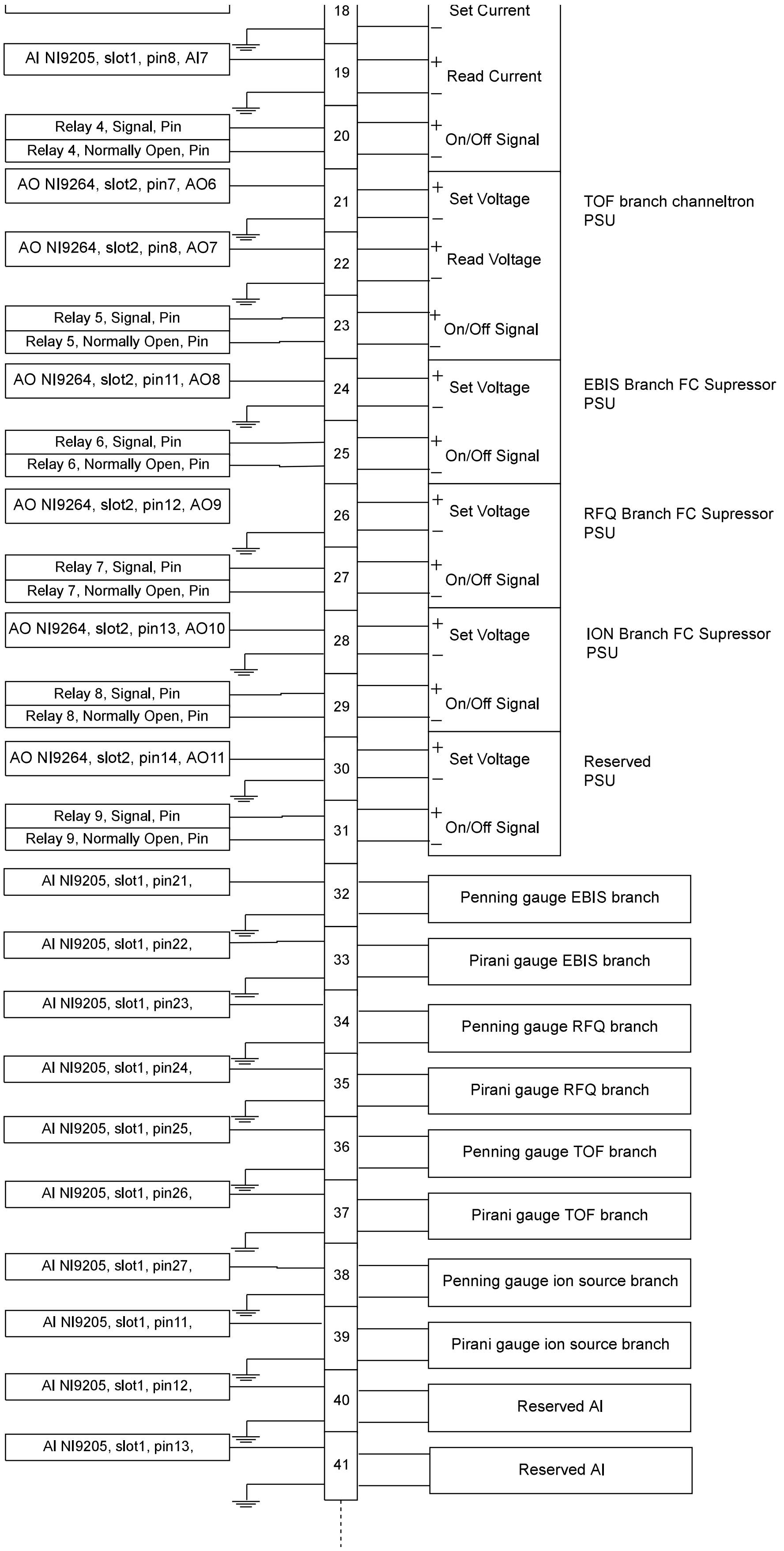
Most LEMOs are 00 and are connect and wired like this.

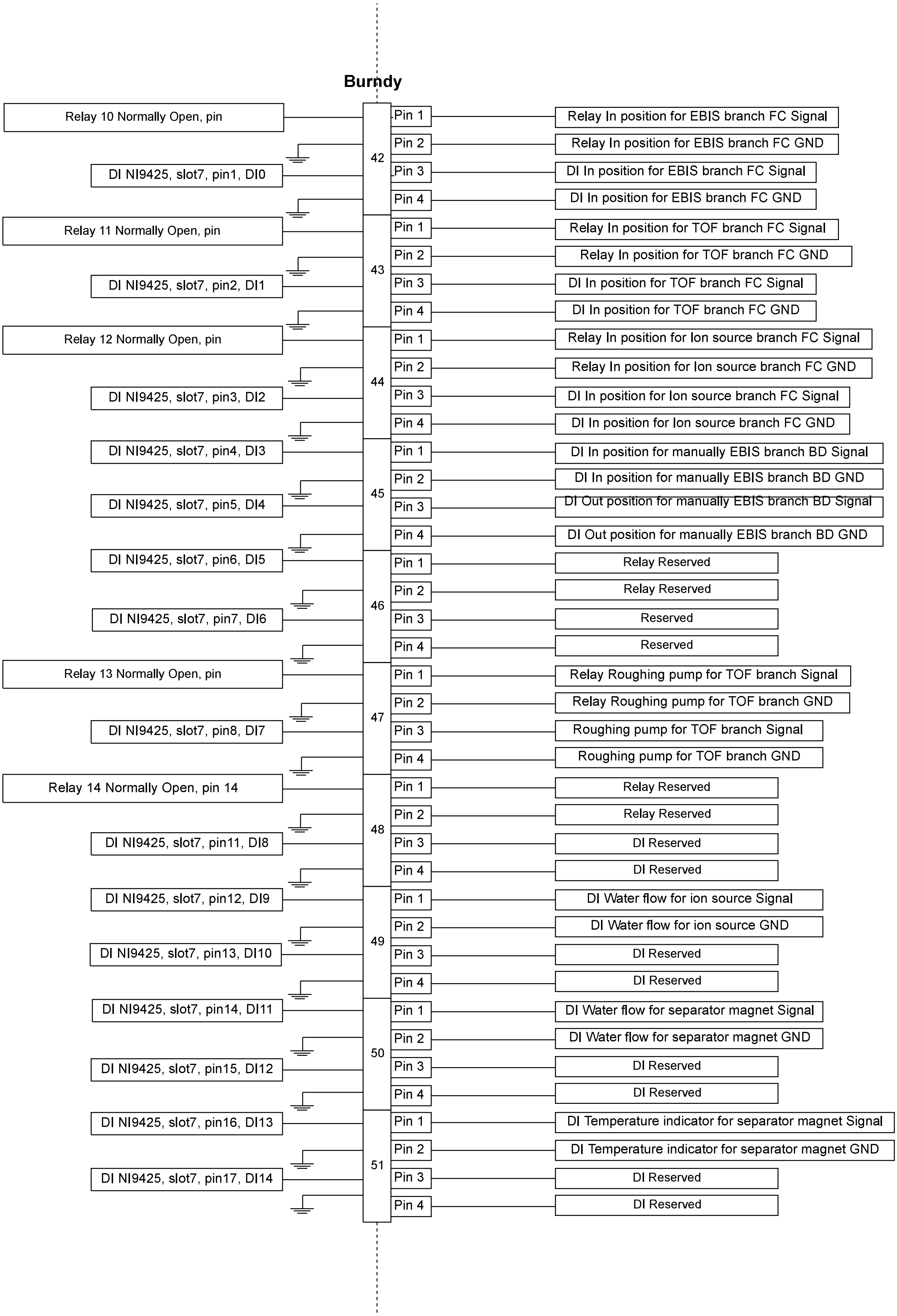


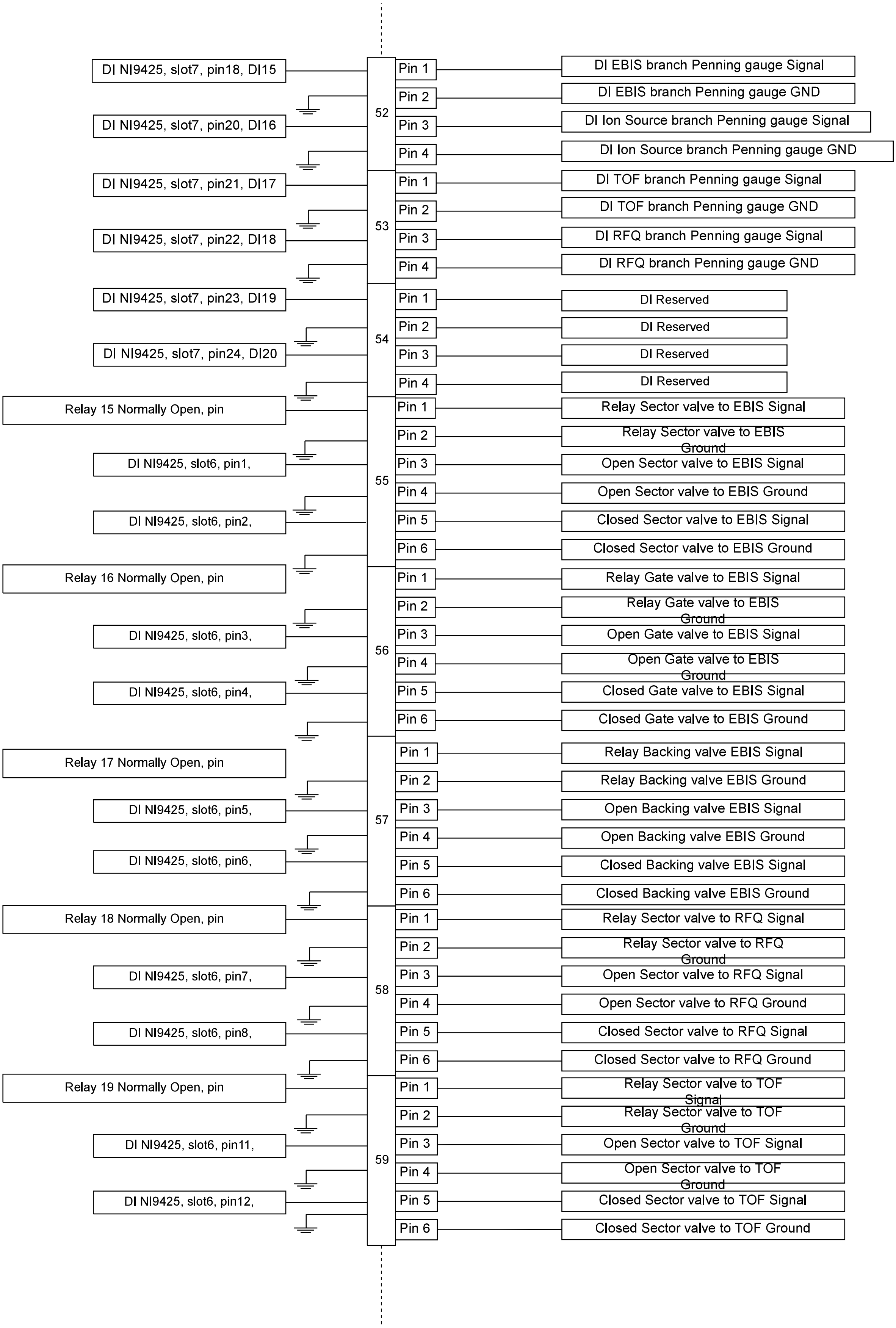
The relay uses LEMO 2 and has this type of connection and wiring

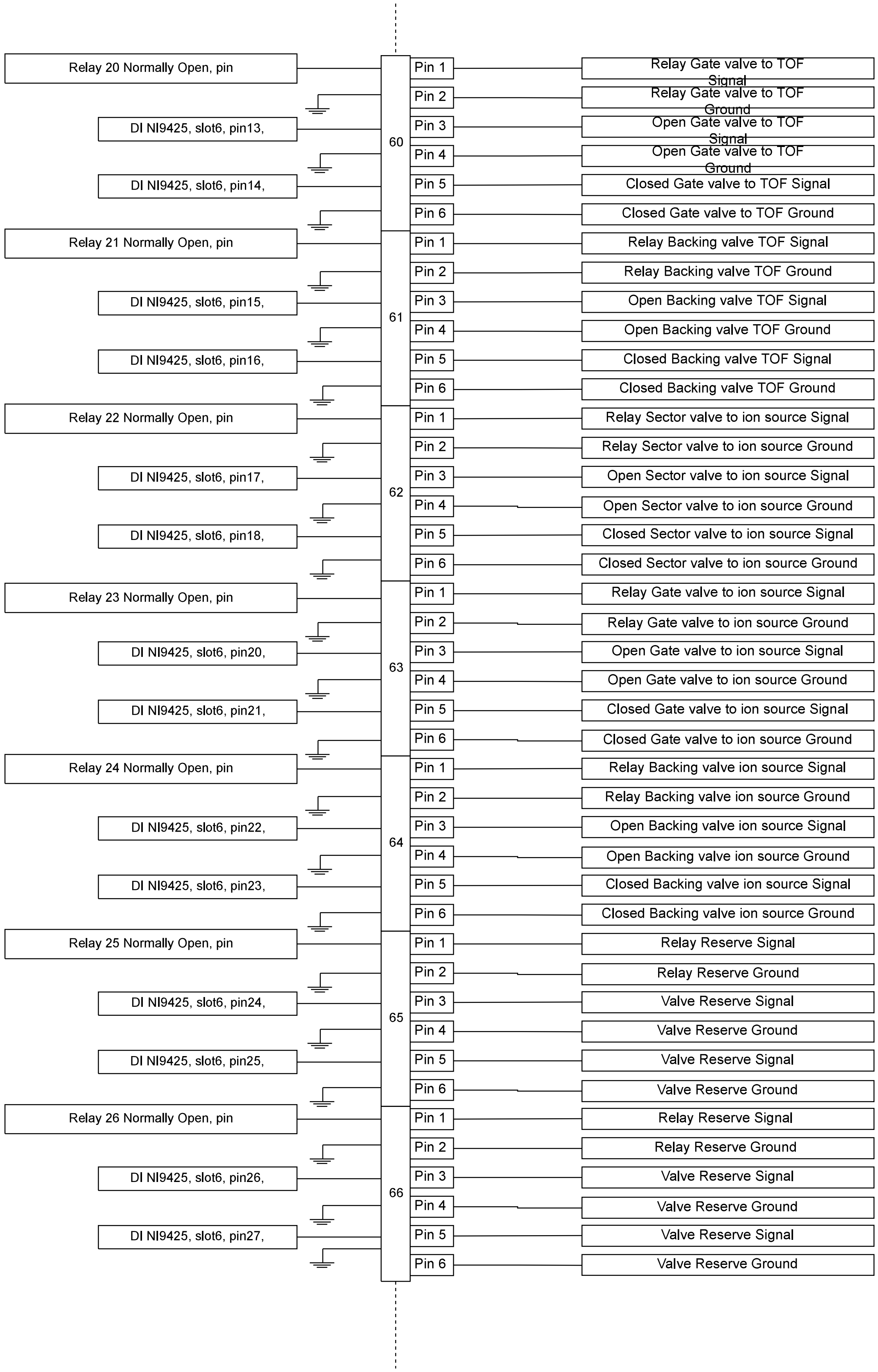


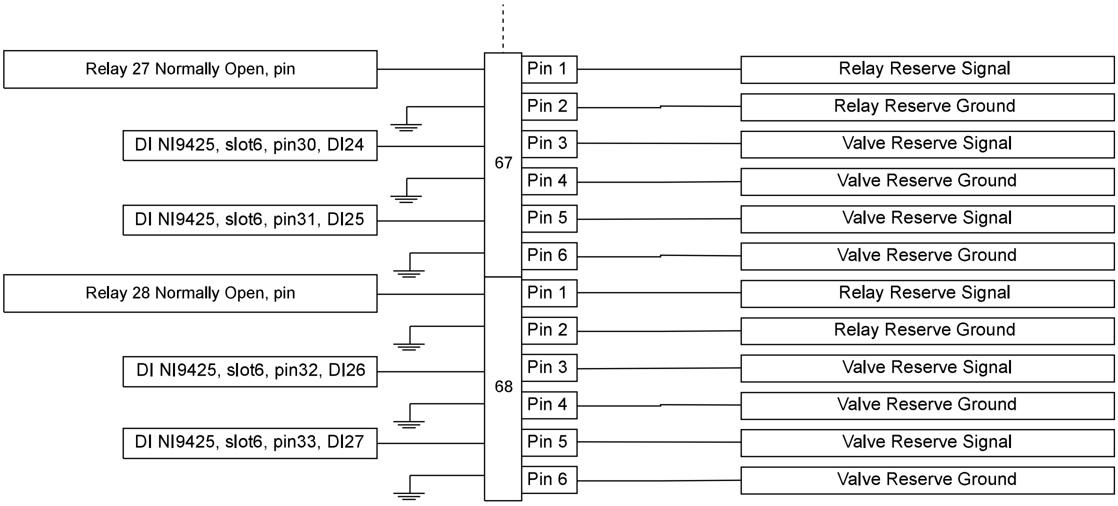



18
Set Current
AI NI9205, slot1, pin8, AI7
19
Read Current
Relay 4, Signal, Pin
Relay 4, Normally Open, Pin
20
On/Off Signal
AO NI9264, slot2, pin7, AO6
21
Set Voltage
TOF branch channeltron PSU
AO NI9264, slot2, pin8, AO7
22
Read Voltage
Relay 5, Signal, Pin
Relay 5, Normally Open, Pin
23
On/Off Signal
AO NI9264, slot2, pin11, AO8
24
Set Voltage
EBIS Branch FC Supressor PSU
Relay 6, Signal, Pin
Relay 6, Normally Open, Pin
25
On/Off Signal
AO NI9264, slot2, pin12, AO9
26
Set Voltage
RFQ Branch FC Supressor PSU
Relay 7, Signal, Pin
Relay 7, Normally Open, Pin
27
On/Off Signal
AO NI9264, slot2, pin13, AO10
28
Set Voltage
ION Branch FC Supressor PSU
Relay 8, Signal, Pin
Relay 8, Normally Open, Pin
29
On/Off Signal
AO NI9264, slot2, pin14, AO11
30
Set Voltage
Reserved PSU
Relay 9, Signal, Pin
Relay 9, Normally Open, Pin
31
On/Off Signal
+
–
AI NI9205, slot1, pin21,
32
Penning gauge EBIS branch
AI NI9205, slot1, pin22,
33
Pirani gauge EBIS branch
AI NI9205, slot1, pin23,
34
Penning gauge RFQ branch
AI NI9205, slot1, pin24,
35
Pirani gauge RFQ branch
AI NI9205, slot1, pin25,
36
Penning gauge TOF branch
AI NI9205, slot1, pin26,
37
Pirani gauge TOF branch
AI NI9205, slot1, pin27,
38
Penning gauge ion source branch
AI NI9205, slot1, pin11,
39
Pirani gauge ion source branch
AI NI9205, slot1, pin12,
40
Reserved AI
AI NI9205, slot1, pin13,
41
Reserved AI


Burndy
Relay 10 Normally Open, pin
DI NI9425, slot7, pin1, DI0
42
Pin 1
Pin 2
Pin 3
Pin 4
Relay In position for EBIS branch FC Signal
Relay In position for EBIS branch FC GND
DI In position for EBIS branch FC Signal
DI In position for EBIS branch FC GND
Relay 11 Normally Open, pin
DI NI9425, slot7, pin2, DI1
43
Pin 1
Pin 2
Pin 3
Pin 4
Relay In position for TOF branch FC Signal
Relay In position for TOF branch FC GND
DI In position for TOF branch FC Signal
DI In position for TOF branch FC GND
Relay 12 Normally Open, pin
DI NI9425, slot7, pin3, DI2
44
Pin 1
Pin 2
Pin 3
Pin 4
Relay In position for Ion source branch FC Signal
Relay In position for Ion source branch FC GND
DI In position for Ion source branch FC Signal
DI In position for Ion source branch FC GND
DI NI9425, slot7, pin4, DI3
DI NI9425, slot7, pin5, DI4
45
Pin 1
Pin 2
Pin 3
Pin 4
DI In position for manually EBIS branch BD Signal
DI In position for manually EBIS branch BD GND
DI Out position for manually EBIS branch BD Signal
DI Out position for manually EBIS branch BD GND
DI NI9425, slot7, pin6, DI5
DI NI9425, slot7, pin7, DI6
46
Pin 1
Pin 2
Pin 3
Pin 4
Relay Reserved
Relay Reserved
Reserved
Reserved
Relay 13 Normally Open, pin
DI NI9425, slot7, pin8, DI7
47
Pin 1
Pin 2
Pin 3
Pin 4
Relay Roughing pump for TOF branch Signal
Relay Roughing pump for TOF branch GND
Roughing pump for TOF branch Signal
Roughing pump for TOF branch GND
Relay 14 Normally Open, pin 14
DI NI9425, slot7, pin11, DI8
48
Pin 1
Pin 2
Pin 3
Pin 4
Relay Reserved
Relay Reserved
DI Reserved
DI Reserved
DI NI9425, slot7, pin12, DI9
DI NI9425, slot7, pin13, DI10
49
Pin 1
Pin 2
Pin 3
Pin 4
DI Water flow for ion source Signal
DI Water flow for ion source GND
DI Reserved
DI Reserved
DI NI9425, slot7, pin14, DI11
DI NI9425, slot7, pin15, DI12
50
Pin 1
Pin 2
Pin 3
Pin 4
DI Water flow for separator magnet Signal
DI Water flow for separator magnet GND
DI Reserved
DI Reserved
DI NI9425, slot7, pin16, DI13
DI NI9425, slot7, pin17, DI14
51
Pin 1
Pin 2
Pin 3
Pin 4
DI Temperature indicator for separator magnet Signal
DI Temperature indicator for separator magnet GND
DI Reserved
DI Reserved


52
DI NI9425, slot7, pin18, DI15
Pin 1
DI EBIS branch Penning gauge Signal
Pin 2
DI EBIS branch Penning gauge GND
DI NI9425, slot7, pin20, DI16
Pin 3
DI Ion Source branch Penning gauge Signal
Pin 4
DI Ion Source branch Penning gauge GND
53
DI NI9425, slot7, pin21, DI17
Pin 1
DI TOF branch Penning gauge Signal
Pin 2
DI TOF branch Penning gauge GND
DI NI9425, slot7, pin22, DI18
Pin 3
DI RFQ branch Penning gauge Signal
Pin 4
DI RFQ branch Penning gauge GND
54
DI NI9425, slot7, pin23, DI19
Pin 1
DI Reserved
Pin 2
DI Reserved
DI NI9425, slot7, pin24, DI20
Pin 3
DI Reserved
Pin 4
DI Reserved
55
Relay 15 Normally Open, pin
Pin 1
Relay Sector valve to EBIS Signal
Pin 2
Relay Sector valve to EBIS Ground
DI NI9425, slot6, pin1,
Pin 3
Open Sector valve to EBIS Signal
Pin 4
Open Sector valve to EBIS Ground
DI NI9425, slot6, pin2,
Pin 5
Closed Sector valve to EBIS Signal
Pin 6
Closed Sector valve to EBIS Ground
56
Relay 16 Normally Open, pin
Pin 1
Relay Gate valve to EBIS Signal
Pin 2
Relay Gate valve to EBIS Ground
DI NI9425, slot6, pin3,
Pin 3
Open Gate valve to EBIS Signal
Pin 4
Open Gate valve to EBIS Ground
DI NI9425, slot6, pin4,
Pin 5
Closed Gate valve to EBIS Signal
Pin 6
Closed Gate valve to EBIS Ground
57
Relay 17 Normally Open, pin
Pin 1
Relay Backing valve EBIS Signal
Pin 2
Relay Backing valve EBIS Ground
DI NI9425, slot6, pin5,
Pin 3
Open Backing valve EBIS Signal
Pin 4
Open Backing valve EBIS Ground
DI NI9425, slot6, pin6,
Pin 5
Closed Backing valve EBIS Signal
Pin 6
Closed Backing valve EBIS Ground
58
Relay 18 Normally Open, pin
Pin 1
Relay Sector valve to RFQ Signal
Pin 2
Relay Sector valve to RFQ Ground
DI NI9425, slot6, pin7,
Pin 3
Open Sector valve to RFQ Signal
Pin 4
Open Sector valve to RFQ Ground
DI NI9425, slot6, pin8,
Pin 5
Closed Sector valve to RFQ Signal
Pin 6
Closed Sector valve to RFQ Ground
59
Relay 19 Normally Open, pin
Pin 1
Relay Sector valve to TOF Signal
Pin 2
Relay Sector valve to TOF Ground
DI NI9425, slot6, pin11,
Pin 3
Open Sector valve to TOF Signal
Pin 4
Open Sector valve to TOF Ground
DI NI9425, slot6, pin12,
Pin 5
Closed Sector valve to TOF Signal
Pin 6
Closed Sector valve to TOF Ground


Relay 20 Normally Open, pin
DI NI9425, slot6, pin13,
DI NI9425, slot6, pin14,
60
Pin 1
Relay Gate valve to TOF Signal
Pin 2
Relay Gate valve to TOF Ground
Pin 3
Open Gate valve to TOF Signal
Pin 4
Open Gate valve to TOF Ground
Pin 5
Closed Gate valve to TOF Signal
Pin 6
Closed Gate valve to TOF Ground
Relay 21 Normally Open, pin
DI NI9425, slot6, pin15,
DI NI9425, slot6, pin16,
61
Pin 1
Relay Backing valve TOF Signal
Pin 2
Relay Backing valve TOF Ground
Pin 3
Open Backing valve TOF Signal
Pin 4
Open Backing valve TOF Ground
Pin 5
Closed Backing valve TOF Signal
Pin 6
Closed Backing valve TOF Ground
Relay 22 Normally Open, pin
DI NI9425, slot6, pin17,
DI NI9425, slot6, pin18,
62
Pin 1
Relay Sector valve to ion source Signal
Pin 2
Relay Sector valve to ion source Ground
Pin 3
Open Sector valve to ion source Signal
Pin 4
Open Sector valve to ion source Ground
Pin 5
Closed Sector valve to ion source Signal
Pin 6
Closed Sector valve to ion source Ground
Relay 23 Normally Open, pin
DI NI9425, slot6, pin20,
DI NI9425, slot6, pin21,
63
Pin 1
Relay Gate valve to ion source Signal
Pin 2
Relay Gate valve to ion source Ground
Pin 3
Open Gate valve to ion source Signal
Pin 4
Open Gate valve to ion source Ground
Pin 5
Closed Gate valve to ion source Signal
Pin 6
Closed Gate valve to ion source Ground
Relay 24 Normally Open, pin
DI NI9425, slot6, pin22,
DI NI9425, slot6, pin23,
64
Pin 1
Relay Backing valve ion source Signal
Pin 2
Relay Backing valve ion source Ground
Pin 3
Open Backing valve ion source Signal
Pin 4
Open Backing valve ion source Ground
Pin 5
Closed Backing valve ion source Signal
Pin 6
Closed Backing valve ion source Ground
Relay 25 Normally Open, pin
DI NI9425, slot6, pin24,
DI NI9425, slot6, pin25,
65
Pin 1
Relay Reserve Signal
Pin 2
Relay Reserve Ground
Pin 3
Valve Reserve Signal
Pin 4
Valve Reserve Ground
Pin 5
Valve Reserve Signal
Pin 6
Valve Reserve Ground
Relay 26 Normally Open, pin
DI NI9425, slot6, pin26,
DI NI9425, slot6, pin27,
66
Pin 1
Relay Reserve Signal
Pin 2
Relay Reserve Ground
Pin 3
Valve Reserve Signal
Pin 4
Valve Reserve Ground
Pin 5
Valve Reserve Signal
Pin 6
Valve Reserve Ground


Relay 27 Normally Open, pin
DI NI9425, slot6, pin30, DI24
DI NI9425, slot6, pin31, DI25
Relay 28 Normally Open, pin
DI NI9425, slot6, pin32, DI26
DI NI9425, slot6, pin33, DI27
67
68
Pin 1
Pin 2
Pin 3
Pin 4
Pin 5
Pin 6
Pin 1
Pin 2
Pin 3
Pin 4
Pin 5
Pin 6
Relay Reserve Signal
Relay Reserve Ground
Valve Reserve Signal
Valve Reserve Ground
Valve Reserve Signal
Valve Reserve Ground
Relay Reserve Signal
Relay Reserve Ground
Valve Reserve Signal
Valve Reserve Ground
Valve Reserve Signal
Valve Reserve Ground

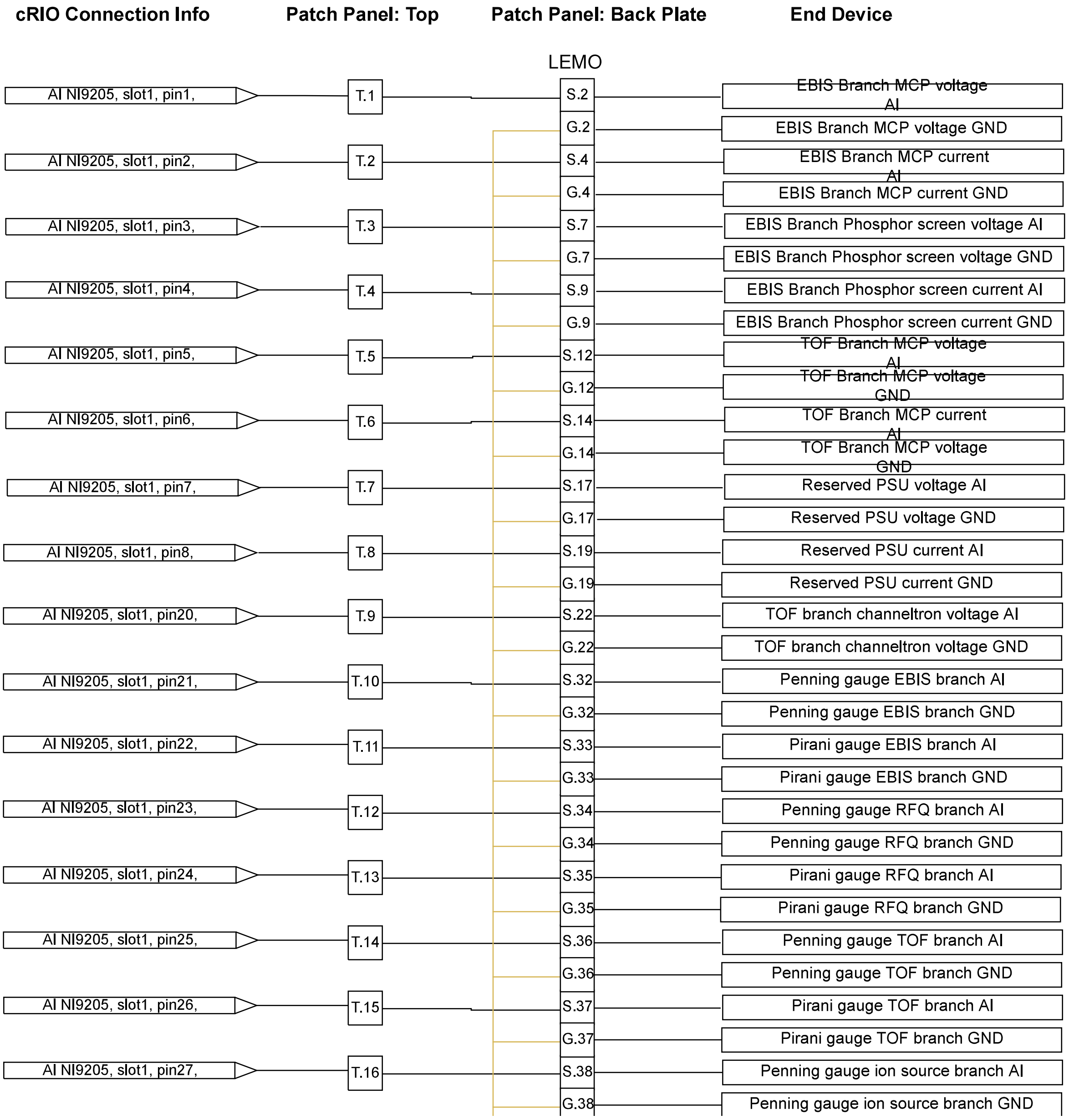
Connection diagram for the Top Screw Terminal

Information

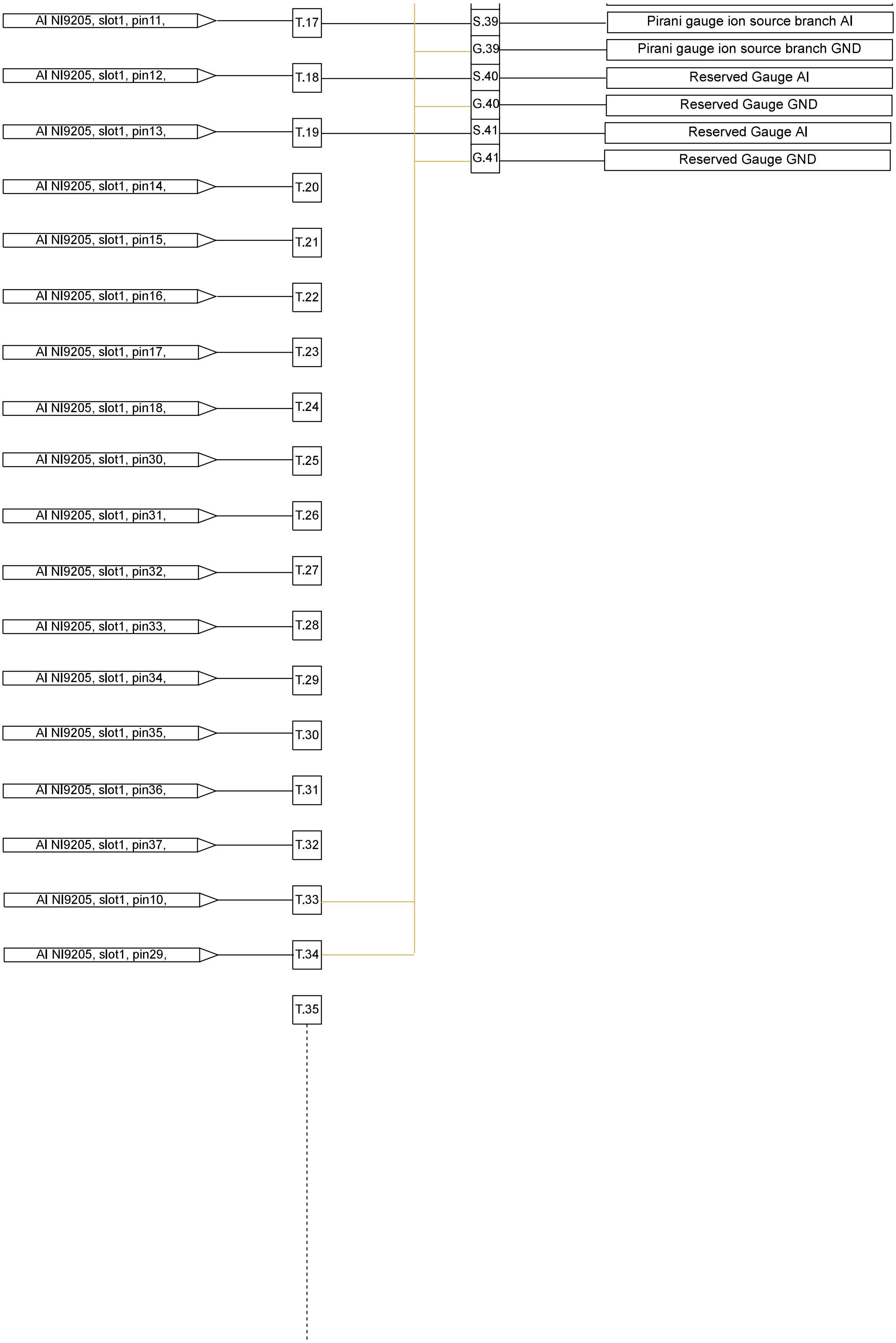
Platform: vacuum water beam
Order: Screw terminal are in ascending order

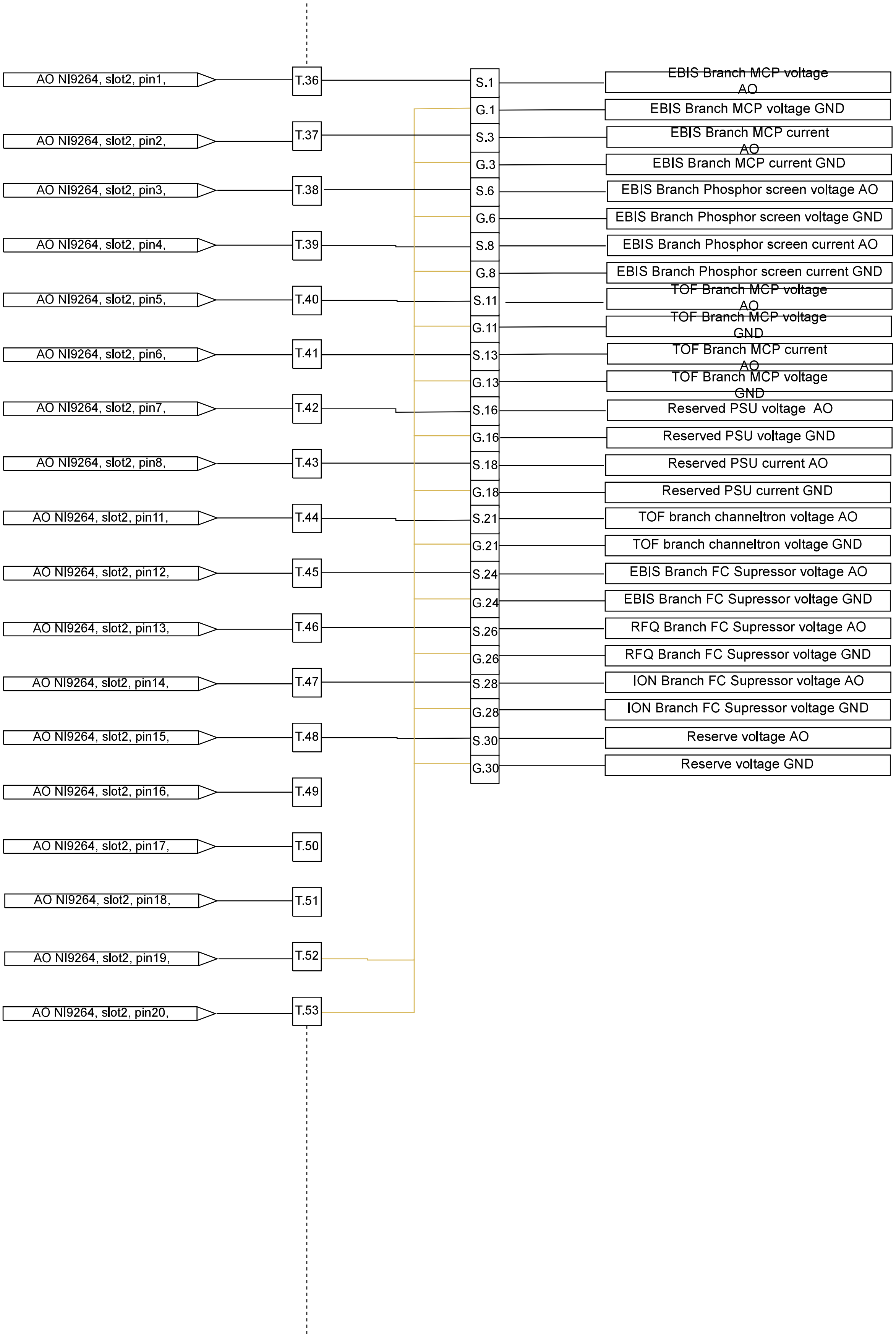
Definitions

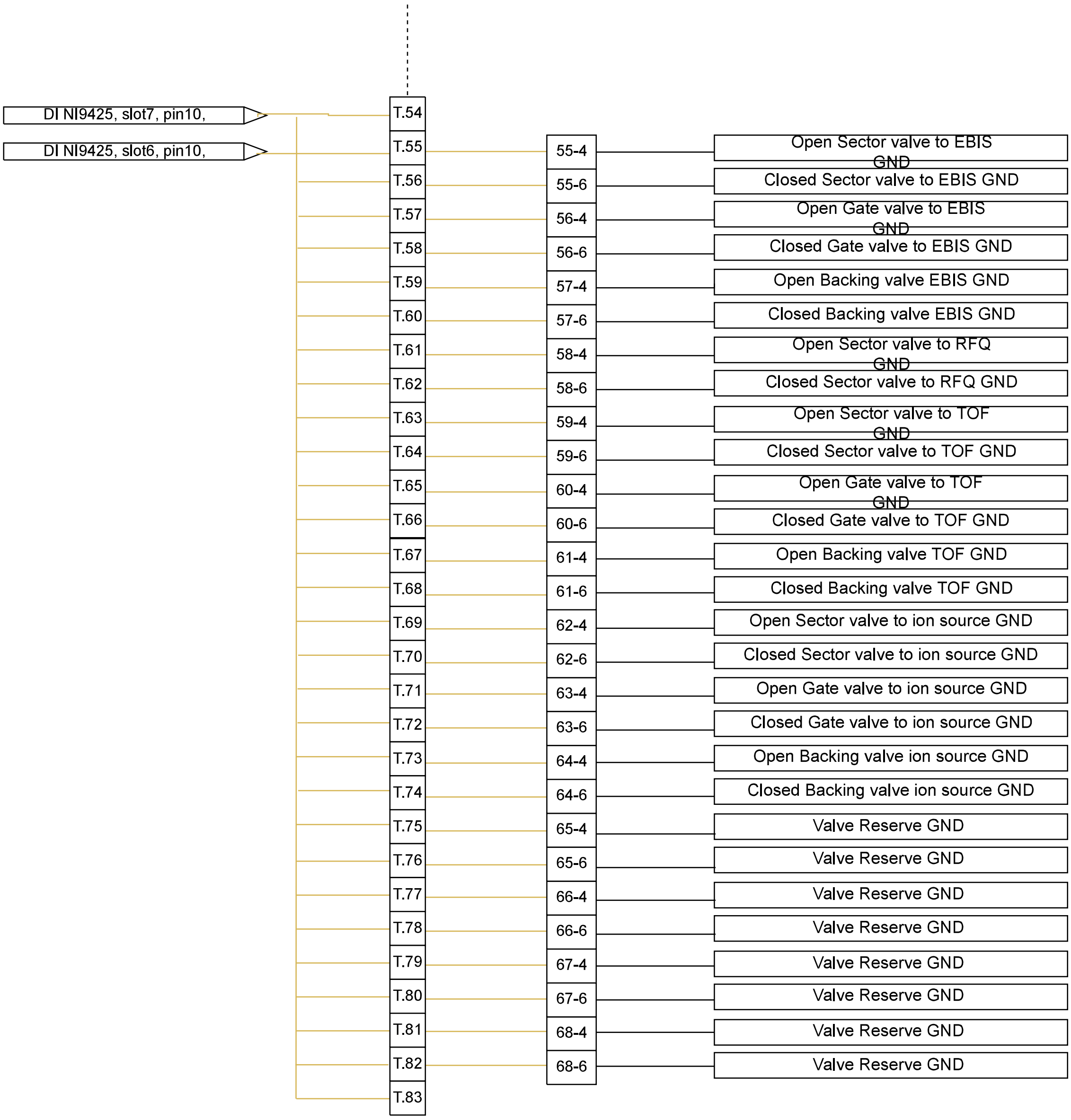
T.x = Top Screw Terminal
S.x = Signal from LEMO connector x
G.x = Ground from LEMO connector x
AI = Analog In
AO = Analog Out
GND = Ground
xx-x = Berndi_connector-berndie_pin



cRIO Connection Info	Patch Panel: Top	Patch Panel: Back Plate	End Device
AI NI9205, slot1, pin1,	T.1	S.2	EBIS Branch MCP voltage AI
		G.2	EBIS Branch MCP voltage GND
AI NI9205, slot1, pin2,	T.2	S.4	EBIS Branch MCP current AI
		G.4	EBIS Branch MCP current GND
AI NI9205, slot1, pin3,	T.3	S.7	EBIS Branch Phosphor screen voltage AI
		G.7	EBIS Branch Phosphor screen voltage GND
AI NI9205, slot1, pin4,	T.4	S.9	EBIS Branch Phosphor screen current AI
		G.9	EBIS Branch Phosphor screen current GND
AI NI9205, slot1, pin5,	T.5	S.12	TOF Branch MCP voltage AI
		G.12	TOF Branch MCP voltage GND
AI NI9205, slot1, pin6,	T.6	S.14	TOF Branch MCP current AI
		G.14	TOF Branch MCP voltage GND
AI NI9205, slot1, pin7,	T.7	S.17	Reserved PSU voltage AI
		G.17	Reserved PSU voltage GND
AI NI9205, slot1, pin8,	T.8	S.19	Reserved PSU current AI
		G.19	Reserved PSU current GND
AI NI9205, slot1, pin20,	T.9	S.22	TOF branch channeltron voltage AI
		G.22	TOF branch channeltron voltage GND
AI NI9205, slot1, pin21,	T.10	S.32	Penning gauge EBIS branch AI
		G.32	Penning gauge EBIS branch GND
AI NI9205, slot1, pin22,	T.11	S.33	Pirani gauge EBIS branch AI
		G.33	Pirani gauge EBIS branch GND
AI NI9205, slot1, pin23,	T.12	S.34	Penning gauge RFQ branch AI
		G.34	Penning gauge RFQ branch GND
AI NI9205, slot1, pin24,	T.13	S.35	Pirani gauge RFQ branch AI
		G.35	Pirani gauge RFQ branch GND
AI NI9205, slot1, pin25,	T.14	S.36	Penning gauge TOF branch AI
		G.36	Penning gauge TOF branch GND
AI NI9205, slot1, pin26,	T.15	S.37	Pirani gauge TOF branch AI
		G.37	Pirani gauge TOF branch GND
AI NI9205, slot1, pin27,	T.16	S.38	Penning gauge ion source branch AI
		G.38	Penning gauge ion source branch GND


AI NI9205, slot1, pin11,
T.17
S.39
Pirani gauge ion source branch AI
G.39
Pirani gauge ion source branch GND
AI NI9205, slot1, pin12,
T.18
S.40
Reserved Gauge AI
G.40
Reserved Gauge GND
AI NI9205, slot1, pin13,
T.19
S.41
Reserved Gauge AI
G.41
Reserved Gauge GND
AI NI9205, slot1, pin14,
T.20
AI NI9205, slot1, pin15,
T.21
AI NI9205, slot1, pin16,
T.22
AI NI9205, slot1, pin17,
T.23
AI NI9205, slot1, pin18,
T.24
AI NI9205, slot1, pin30,
T.25
AI NI9205, slot1, pin31,
T.26
AI NI9205, slot1, pin32,
T.27
AI NI9205, slot1, pin33,
T.28
AI NI9205, slot1, pin34,
T.29
AI NI9205, slot1, pin35,
T.30
AI NI9205, slot1, pin36,
T.31
AI NI9205, slot1, pin37,
T.32
AI NI9205, slot1, pin10,
T.33
AI NI9205, slot1, pin29,
T.34
T.35


AO NI9264, slot2, pin1,
T.36
S.1
EBIS Branch MCP voltage AO
G.1
EBIS Branch MCP voltage GND
AO NI9264, slot2, pin2,
T.37
S.3
EBIS Branch MCP current AO
G.3
EBIS Branch MCP current GND
AO NI9264, slot2, pin3,
T.38
S.6
EBIS Branch Phosphor screen voltage AO
G.6
EBIS Branch Phosphor screen voltage GND
AO NI9264, slot2, pin4,
T.39
S.8
EBIS Branch Phosphor screen current AO
G.8
EBIS Branch Phosphor screen current GND
AO NI9264, slot2, pin5,
T.40
S.11
TOF Branch MCP voltage AO
G.11
TOF Branch MCP voltage GND
AO NI9264, slot2, pin6,
T.41
S.13
TOF Branch MCP current AO
G.13
TOF Branch MCP voltage GND
AO NI9264, slot2, pin7,
T.42
S.16
Reserved PSU voltage AO
G.16
Reserved PSU voltage GND
AO NI9264, slot2, pin8,
T.43
S.18
Reserved PSU current AO
G.18
Reserved PSU current GND
AO NI9264, slot2, pin11,
T.44
S.21
TOF branch channeltron voltage AO
G.21
TOF branch channeltron voltage GND
AO NI9264, slot2, pin12,
T.45
S.24
EBIS Branch FC Supressor voltage AO
G.24
EBIS Branch FC Supressor voltage GND
AO NI9264, slot2, pin13,
T.46
S.26
RFQ Branch FC Supressor voltage AO
G.26
RFQ Branch FC Supressor voltage GND
AO NI9264, slot2, pin14,
T.47
S.28
ION Branch FC Supressor voltage AO
G.28
ION Branch FC Supressor voltage GND
AO NI9264, slot2, pin15,
T.48
S.30
Reserve voltage AO
G.30
Reserve voltage GND
AO NI9264, slot2, pin16,
T.49
AO NI9264, slot2, pin17,
T.50
AO NI9264, slot2, pin18,
T.51
AO NI9264, slot2, pin19,
T.52
AO NI9264, slot2, pin20,
T.53

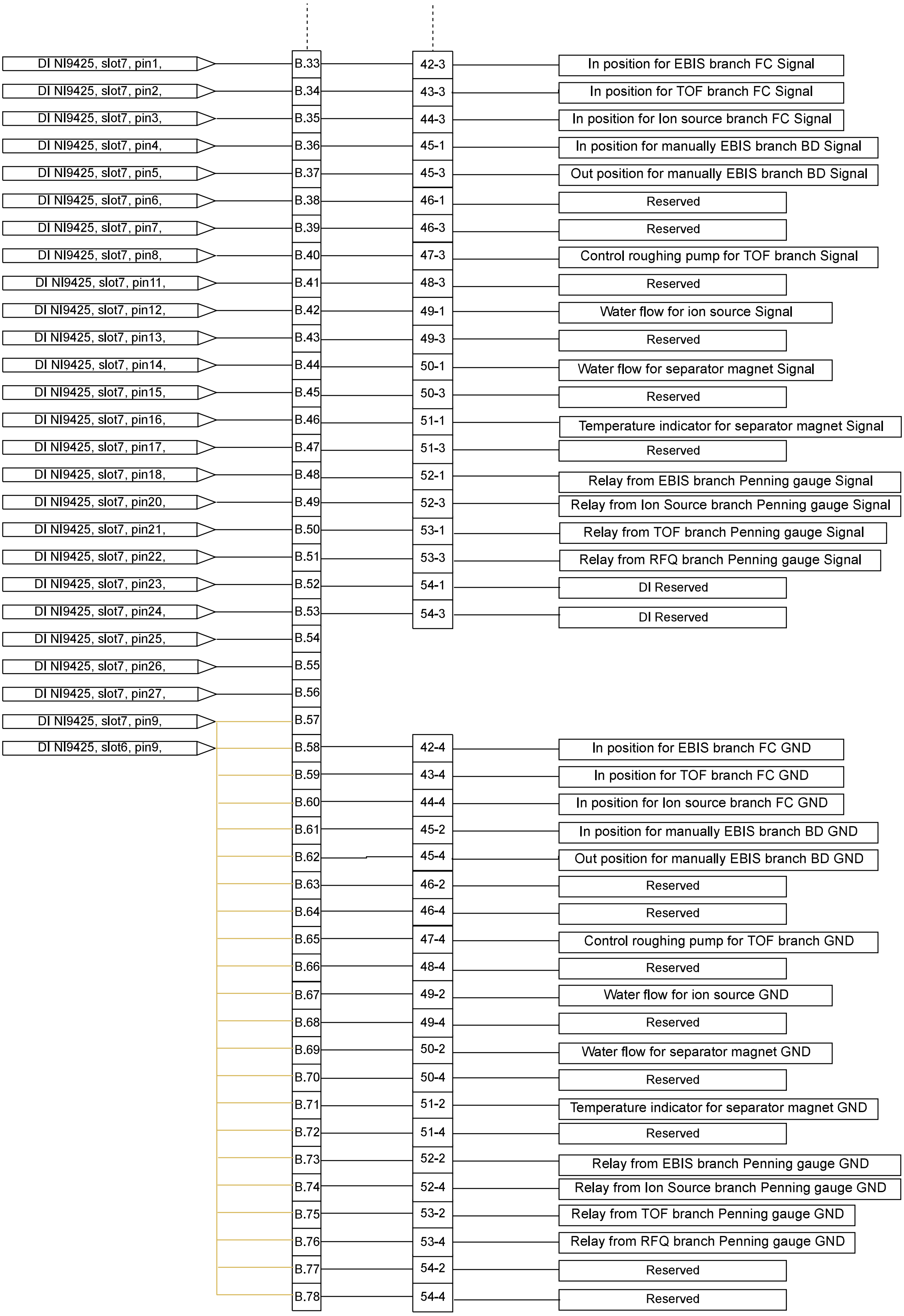

DI NI9425, slot7, pin10,
DI NI9425, slot6, pin10,
T.54
T.55
55-4
Open Sector valve to EBIS GND
T.56
55-6
Closed Sector valve to EBIS GND
T.57
56-4
Open Gate valve to EBIS GND
T.58
56-6
Closed Gate valve to EBIS GND
T.59
57-4
Open Backing valve EBIS GND
T.60
57-6
Closed Backing valve EBIS GND
T.61
58-4
Open Sector valve to RFQ GND
T.62
58-6
Closed Sector valve to RFQ GND
T.63
59-4
Open Sector valve to TOF GND
T.64
59-6
Closed Sector valve to TOF GND
T.65
60-4
Open Gate valve to TOF GND
T.66
60-6
Closed Gate valve to TOF GND
T.67
61-4
Open Backing valve TOF GND
T.68
61-6
Closed Backing valve TOF GND
T.69
62-4
Open Sector valve to ion source GND
T.70
62-6
Closed Sector valve to ion source GND
T.71
63-4
Open Gate valve to ion source GND
T.72
63-6
Closed Gate valve to ion source GND
T.73
64-4
Open Backing valve ion source GND
T.74
64-6
Closed Backing valve ion source GND
T.75
65-4
Valve Reserve GND
T.76
65-6
Valve Reserve GND
T.77
66-4
Valve Reserve GND
T.78
66-6
Valve Reserve GND
T.79
67-4
Valve Reserve GND
T.80
67-6
Valve Reserve GND
T.81
68-4
Valve Reserve GND
T.82
68-6
Valve Reserve GND
T.83

Connection diagram for the Bottom Screw Terminal

Information
cRIO: Vacuum&Water, and Beam diagnostic
Order: Screw terminal are in ascending order

Definitions
B.x = Top Screw Terminal
GND = Ground
xx-x = Berndi_connector-berndie_pin

cRIO Connection Info	Patch Panel: Bottom	Patch Panel: Back Plate	End Device
DI NI9425, slot6, pin1,	B.1	55-3	Open Sector valve to EBIS Signal
DI NI9425, slot6, pin2,	B.2	55-5	Closed Sector valve to EBIS Signal
DI NI9425, slot6, pin3,	B.3	56-3	Open Gate valve to EBIS Signal
DI NI9425, slot6, pin4,	B.4	56-5	Closed Gate valve to EBIS Signal
DI NI9425, slot6, pin5,	B.5	57-3	Open Backing valve EBIS Signal
DI NI9425, slot6, pin6,	B.6	57-5	Closed Backing valve EBIS Signal
DI NI9425, slot6, pin7,	B.7	58-3	Open Sector valve to RFQ Signal
DI NI9425, slot6, pin8,	B.8	58-5	Closed Sector valve to RFQ Signal
DI NI9425, slot6, pin11,	B.9	59-3	Open Sector valve to TOF Signal
DI NI9425, slot6, pin12,	B.10	59-5	Closed Sector valve to TOF Signal
DI NI9425, slot6, pin13,	B.11	60-3	Open Gate valve to TOF Signal
DI NI9425, slot6, pin14,	B.12	60-5	Closed Gate valve to TOF Signal
DI NI9425, slot6, pin15,	B.13	61-3	Open Backing valve TOF Signal
DI NI9425, slot6, pin16,	B.14	61-5	Closed Backing valve TOF Signal
DI NI9425, slot6, pin17,	B.15	62-3	Open Sector valve to ion source Signal
DI NI9425, slot6, pin18,	B.16	62-5	Closed Sector valve to ion source Signal
DI NI9425, slot6, pin20,	B.17	63-3	Open Gate valve to ion source Signal
DI NI9425, slot6, pin21,	B.18	63-5	Closed Gate valve to ion source Signal
DI NI9425, slot6, pin22,	B.19	64-3	Open Backing valve ion source Signal
DI NI9425, slot6, pin23,	B.20	64-5	Closed Backing valve ion source Signal
DI NI9425, slot6, pin24,	B.21	65-3	Valve Reserve Signal
DI NI9425, slot6, pin25,	B.22	65-5	Valve Reserve Signal
DI NI9425, slot6, pin26,	B.23	66-3	Valve Reserve Signal
DI NI9425, slot6, pin27,	B.24	66-5	Valve Reserve Signal
DI NI9425, slot6, pin30,	B.25	67-3	Valve Reserve Signal
DI NI9425, slot6, pin31,	B.26	67-5	Valve Reserve Signal
DI NI9425, slot6, pin32,	B.27	68-3	Valve Reserve Signal
DI NI9425, slot6, pin33,	B.28	68-5	Valve Reserve Signal
DI NI9425, slot6, pin34,	B.29		
DI NI9425, slot6, pin35,	B.30		
DI NI9425, slot6, pin36,	B.31		
DI NI9425, slot6, pin37,	B.32		



DI NI9425, slot7, pin1,	B.33	42-3	In position for EBIS branch FC Signal
DI NI9425, slot7, pin2,	B.34	43-3	In position for TOF branch FC Signal
DI NI9425, slot7, pin3,	B.35	44-3	In position for Ion source branch FC Signal
DI NI9425, slot7, pin4,	B.36	45-1	In position for manually EBIS branch BD Signal
DI NI9425, slot7, pin5,	B.37	45-3	Out position for manually EBIS branch BD Signal
DI NI9425, slot7, pin6,	B.38	46-1	Reserved
DI NI9425, slot7, pin7,	B.39	46-3	Reserved
DI NI9425, slot7, pin8,	B.40	47-3	Control roughing pump for TOF branch Signal
DI NI9425, slot7, pin11,	B.41	48-3	Reserved
DI NI9425, slot7, pin12,	B.42	49-1	Water flow for ion source Signal
DI NI9425, slot7, pin13,	B.43	49-3	Reserved
DI NI9425, slot7, pin14,	B.44	50-1	Water flow for separator magnet Signal
DI NI9425, slot7, pin15,	B.45	50-3	Reserved
DI NI9425, slot7, pin16,	B.46	51-1	Temperature indicator for separator magnet Signal
DI NI9425, slot7, pin17,	B.47	51-3	Reserved
DI NI9425, slot7, pin18,	B.48	52-1	Relay from EBIS branch Penning gauge Signal
DI NI9425, slot7, pin20,	B.49	52-3	Relay from Ion Source branch Penning gauge Signal
DI NI9425, slot7, pin21,	B.50	53-1	Relay from TOF branch Penning gauge Signal
DI NI9425, slot7, pin22,	B.51	53-3	Relay from RFQ branch Penning gauge Signal
DI NI9425, slot7, pin23,	B.52	54-1	DI Reserved
DI NI9425, slot7, pin24,	B.53	54-3	DI Reserved
DI NI9425, slot7, pin25,	B.54		
DI NI9425, slot7, pin26,	B.55		
DI NI9425, slot7, pin27,	B.56		
DI NI9425, slot7, pin9,	B.57		
DI NI9425, slot6, pin9,	B.58	42-4	In position for EBIS branch FC GND
	B.59	43-4	In position for TOF branch FC GND
	B.60	44-4	In position for Ion source branch FC GND
	B.61	45-2	In position for manually EBIS branch BD GND
	B.62	45-4	Out position for manually EBIS branch BD GND
	B.63	46-2	Reserved
	B.64	46-4	Reserved
	B.65	47-4	Control roughing pump for TOF branch GND
	B.66	48-4	Reserved
	B.67	49-2	Water flow for ion source GND
	B.68	49-4	Reserved
	B.69	50-2	Water flow for separator magnet GND
	B.70	50-4	Reserved
	B.71	51-2	Temperature indicator for separator magnet GND
	B.72	51-4	Reserved
	B.73	52-2	Relay from EBIS branch Penning gauge GND
	B.74	52-4	Relay from Ion Source branch Penning gauge GND
	B.75	53-2	Relay from TOF branch Penning gauge GND
	B.76	53-4	Relay from RFQ branch Penning gauge GND
	B.77	54-2	Reserved
	B.78	54-4	Reserved

Connection diagram for the relays

Information

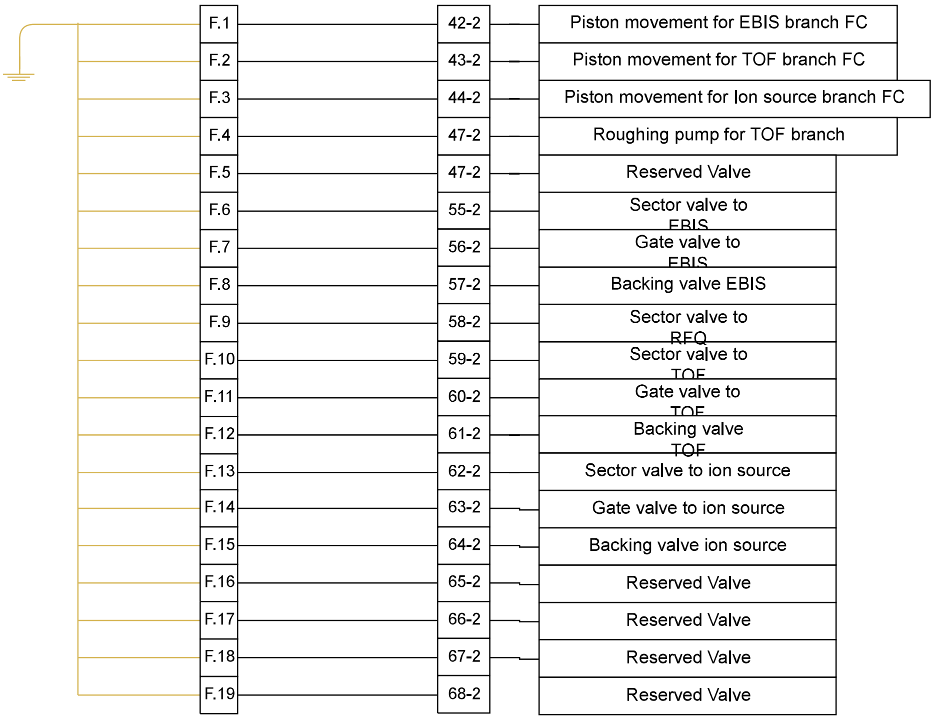
cRIO: Vacuum&Water, and Beam diagnostic
Order: Relay are in ascending order

Definitions

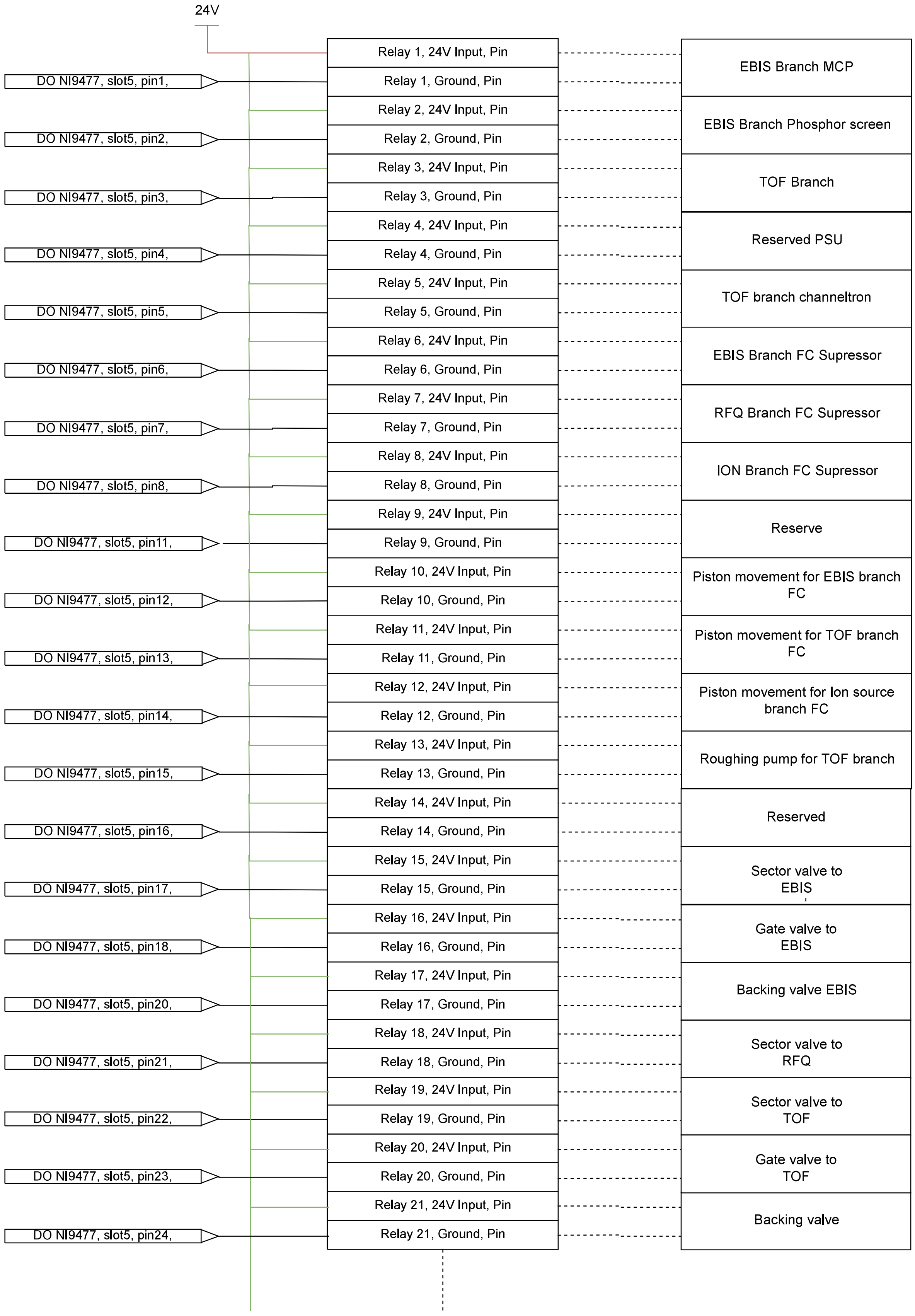
LB.x = Bottom connector from LEMO connector x
LT.x = Top connector from LEMO connector x
xx-x = Berndi_connector-berndie_pin

Relay	Patch Panel: Back Plate	End Device
Relay 1 Signal In, Pin	LB.5	EBIS Branch MCP
Relay 1 Normally Open, pin	LT.5	
Relay 2 Signal In, Pin	LB.10	EBIS Branch Phosphor screen
Relay 2 Normally Open, pin	LT.10	
Relay 3 Signal In, Pin	LB.15	TOF Branch
Relay 3 Normally Open, pin	LT.15	
Relay 4 Signal In, Pin	LB.20	Reserved PSU
Relay 4 Normally Open, pin	LT.20	
Relay 5 Signal In, Pin	LB.23	TOF branch channeltron
Relay 5 Normally Open, pin	LT.23	
Relay 6 Signal In, Pin	LB.25	EBIS Branch FC Supressor
Relay 6 Normally Open, pin	LT.25	
Relay 7 Signal In, Pin	LB.27	RFQ Branch FC Supressor
Relay 7 Normally Open, pin	LT.27	
Relay 8 Signal In, Pin	LB.29	ION Branch FC Supressor
Relay 8 Normally Open, pin	LT.29	
Relay 9 Signal In, Pin	LB.31	Reserve
Relay 9 Normally Open, pin	LT.31	
Relay 10 Signal In, Pin		24V
Relay 10 Normally Open, pin	42-1	Piston movement for EBIS branch FC
Relay 11 Signal In, Pin		24V
Relay 11 Normally Open, pin	43-1	Piston movement for TOF branch FC
Relay 12 Signal In, Pin		24V
Relay 12 Normally Open, pin	44-1	Piston movement for Ion source branch FC
Relay 13 Signal In, Pin		24V
Relay 13 Normally Open, pin	47-1	Roughing pump for TOF branch
Relay 14 Signal In, Pin		24V
Relay 14 Normally Open, pin	48-1	Reserved Valve
Relay 15 Signal In, Pin		24V
Relay 15 Normally Open, pin	55-1	Sector valve to EBIS
Relay 16 Signal In, Pin		24V
Relay 16 Normally Open, pin	56-1	Gate valve to EBIS
Relay 17 Signal In, Pin		24V
Relay 17 Normally Open, pin	57-1	Backing valve EBIS
Relay 18 Signal In, Pin		24V
Relay 18 Normally Open, pin	58-1	Sector valve to RFQ

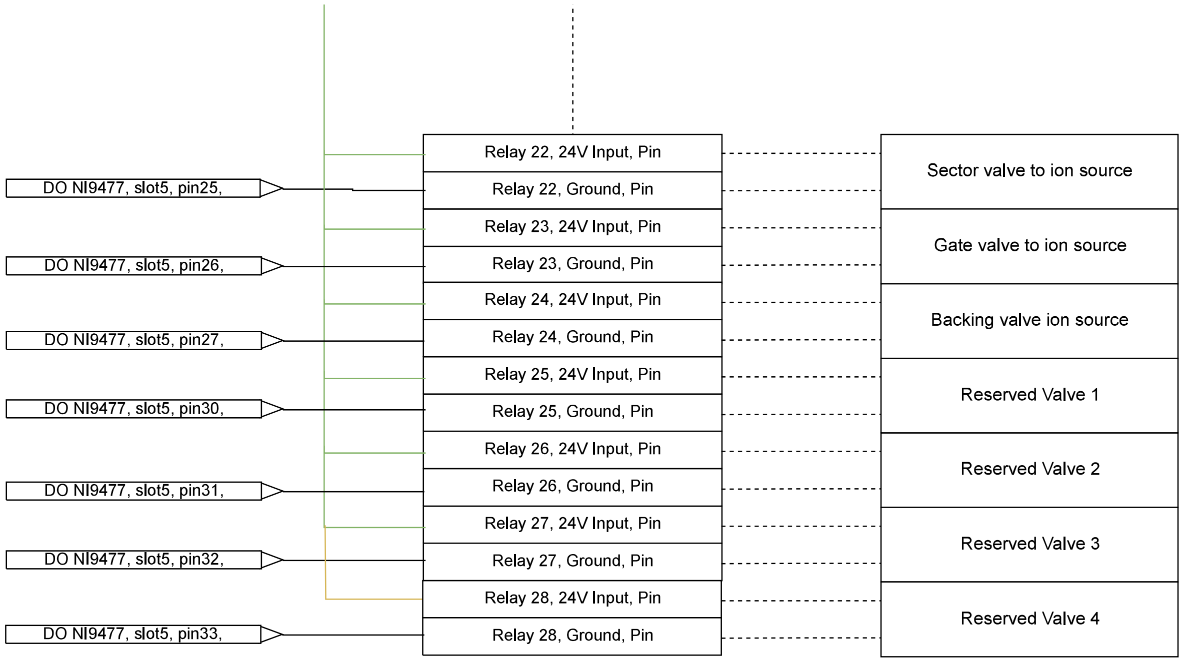
Relay 19 Signal In, Pin		24V
Relay 19 Normally Open, pin	59-1	Sector valve to TOF
Relay 20 Signal In, Pin		24V
Relay 20 Normally Open, pin	60-1	Gate valve to TOF
Relay 21 Signal In, Pin		24V
Relay 21 Normally Open, pin	61-1	Backing valve TOF
Relay 22 Signal In, Pin		24V
Relay 22 Normally Open, pin	62-1	Sector valve to ion source
Relay 23 Signal In, Pin		24V
Relay 23 Normally Open, pin	63-1	Gate valve to ion source
Relay 24 Signal In, Pin		24V
Relay 24 Normally Open, pin	64-1	Backing valve ion source
Relay 25 Signal In, Pin		24V
Relay 25 Normally Open, pin	65-1	Reserved Valve
Relay 26 Signal In, Pin		24V
Relay 26 Normally Open, pin	66-1	Reserved Valve
Relay 27 Signal In, Pin		24V
Relay 27 Normally Open, pin	67-1	Reserved Valve
Relay 28 Signal In, Pin		24V
Relay 28 Normally Open, pin	68-1	Reserved Valve



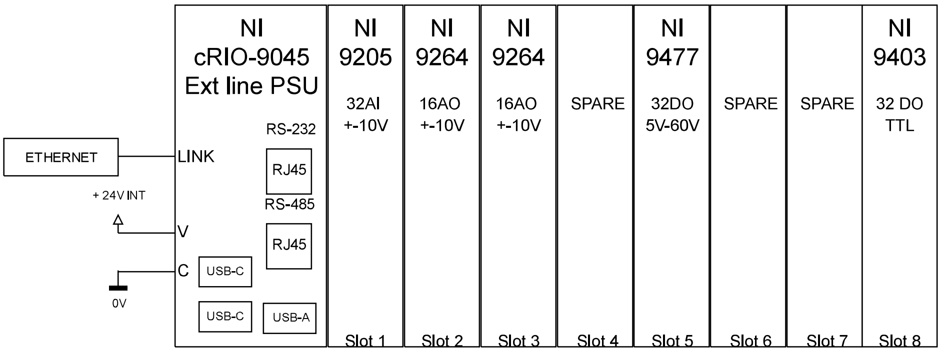
F.1	42-2	Piston movement for EBIS branch FC
F.2	43-2	Piston movement for TOF branch FC
F.3	44-2	Piston movement for Ion source branch FC
F.4	47-2	Roughing pump for TOF branch
F.5	47-2	Reserved Valve
F.6	55-2	Sector valve to EBIS
F.7	56-2	Gate valve to EBIS
F.8	57-2	Backing valve EBIS
F.9	58-2	Sector valve to RFQ
F.10	59-2	Sector valve to TOF
F.11	60-2	Gate valve to TOF
F.12	61-2	Backing valve TOF
F.13	62-2	Sector valve to ion source
F.14	63-2	Gate valve to ion source
F.15	64-2	Backing valve ion source
F.16	65-2	Reserved Valve
F.17	66-2	Reserved Valve
F.18	67-2	Reserved Valve
F.19	68-2	Reserved Valve



	Relay 1, 24V Input, Pin	EBIS Branch MCP
DO NI9477, slot5, pin1,	Relay 1, Ground, Pin	
	Relay 2, 24V Input, Pin	EBIS Branch Phosphor screen
DO NI9477, slot5, pin2,	Relay 2, Ground, Pin	
	Relay 3, 24V Input, Pin	TOF Branch
DO NI9477, slot5, pin3,	Relay 3, Ground, Pin	
	Relay 4, 24V Input, Pin	Reserved PSU
DO NI9477, slot5, pin4,	Relay 4, Ground, Pin	
	Relay 5, 24V Input, Pin	TOF branch channeltron
DO NI9477, slot5, pin5,	Relay 5, Ground, Pin	
	Relay 6, 24V Input, Pin	EBIS Branch FC Supressor
DO NI9477, slot5, pin6,	Relay 6, Ground, Pin	
	Relay 7, 24V Input, Pin	RFQ Branch FC Supressor
DO NI9477, slot5, pin7,	Relay 7, Ground, Pin	
	Relay 8, 24V Input, Pin	ION Branch FC Supressor
DO NI9477, slot5, pin8,	Relay 8, Ground, Pin	
	Relay 9, 24V Input, Pin	Reserve
DO NI9477, slot5, pin11,	Relay 9, Ground, Pin	
	Relay 10, 24V Input, Pin	Piston movement for EBIS branch FC
DO NI9477, slot5, pin12,	Relay 10, Ground, Pin	
	Relay 11, 24V Input, Pin	Piston movement for TOF branch FC
DO NI9477, slot5, pin13,	Relay 11, Ground, Pin	
	Relay 12, 24V Input, Pin	Piston movement for Ion source branch FC
DO NI9477, slot5, pin14,	Relay 12, Ground, Pin	
	Relay 13, 24V Input, Pin	Roughing pump for TOF branch
DO NI9477, slot5, pin15,	Relay 13, Ground, Pin	
	Relay 14, 24V Input, Pin	Reserved
DO NI9477, slot5, pin16,	Relay 14, Ground, Pin	
	Relay 15, 24V Input, Pin	Sector valve to EBIS
DO NI9477, slot5, pin17,	Relay 15, Ground, Pin	
	Relay 16, 24V Input, Pin	Gate valve to EBIS
DO NI9477, slot5, pin18,	Relay 16, Ground, Pin	
	Relay 17, 24V Input, Pin	Backing valve EBIS
DO NI9477, slot5, pin20,	Relay 17, Ground, Pin	
	Relay 18, 24V Input, Pin	Sector valve to RFQ
DO NI9477, slot5, pin21,	Relay 18, Ground, Pin	
	Relay 19, 24V Input, Pin	Sector valve to TOF
DO NI9477, slot5, pin22,	Relay 19, Ground, Pin	
	Relay 20, 24V Input, Pin	Gate valve to TOF
DO NI9477, slot5, pin23,	Relay 20, Ground, Pin	
	Relay 21, 24V Input, Pin	Backing valve
DO NI9477, slot5, pin24,	Relay 21, Ground, Pin	


Relay 22, 24V Input, Pin
DO NI9477, slot5, pin25,
Relay 22, Ground, Pin
Sector valve to ion source
Relay 23, 24V Input, Pin
DO NI9477, slot5, pin26,
Relay 23, Ground, Pin
Gate valve to ion source
Relay 24, 24V Input, Pin
DO NI9477, slot5, pin27,
Relay 24, Ground, Pin
Backing valve ion source
Relay 25, 24V Input, Pin
DO NI9477, slot5, pin30,
Relay 25, Ground, Pin
Reserved Valve 1
Relay 26, 24V Input, Pin
DO NI9477, slot5, pin31,
Relay 26, Ground, Pin
Reserved Valve 2
Relay 27, 24V Input, Pin
DO NI9477, slot5, pin32,
Relay 27, Ground, Pin
Reserved Valve 3
Relay 28, 24V Input, Pin
DO NI9477, slot5, pin33,
Relay 28, Ground, Pin
Reserved Valve 4

cRIO Module setup and connection



TwinEBIS	ECHELLE SCALE	SH-CERN	NOM/NAME	DATE
		APPRO.		
		CONTROL		
cRIO Beam Optics		DES/DRA.	*Steen*	2019-05-03
		REMPLACE/REPLACES		
		IND.		

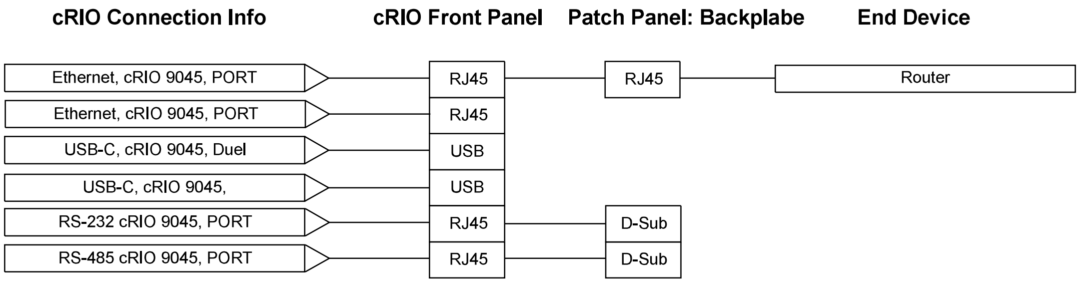
Connection Diagram from the cRIO Front Panel

Information

cRIO: Ext. Line PSU
Perspective: cRIO Front panel

Definitions

D-Sub X = D-sub connector



Connection Diagram for the Analog Input Module

Information

cRIO: ext. line psu
Perspective: Analog Inputs are in ascending order

Definitions

T.x = Top Screw Terminal

cRIO Connection Info	Patch Panel: Top	End Device
AI NI9205, slot1, pin1,	T.1	Vertical deflector RFQ up voltage
AI NI9205, slot1, pin2,	T.2	Vertical deflector RFQ down voltage
AI NI9205, slot1, pin3,	T.3	Horizontal deflector RFQ left voltage
AI NI9205, slot1, pin4,	T.4	Horizontal deflector RFQ right voltage
AI NI9205, slot1, pin5,	T.5	Vertical deflector ion 1 up voltage
AI NI9205, slot1, pin6,	T.6	Vertical deflector ion 1 down voltage
AI NI9205, slot1, pin7,	T.7	Horizontal deflector ion 1 left voltage
AI NI9205, slot1, pin8,	T.8	Horizontal deflector ion 1 right voltage
AI NI9205, slot1, pin20,	T.9	Vertical deflector ion 2 up voltage
AI NI9205, slot1, pin21,	T.10	Vertical deflector ion 2 down voltage
AI NI9205, slot1, pin22,	T.11	Horizontal deflector ion 2 left voltage
AI NI9205, slot1, pin23,	T.12	Horizontal deflector ion 2 right voltage
AI NI9205, slot1, pin24,	T.13	Vertical deflector ion 3 up voltage
AI NI9205, slot1, pin25,	T.14	Vertical deflector ion 3 down voltage
AI NI9205, slot1, pin26,	T.15	Horizontal deflector ion 3 left voltage
AI NI9205, slot1, pin27,	T.16	Horizontal deflector ion 3 right voltage
AI NI9205, slot1, pin11,	T.17	EBIS HV
AI NI9205, slot1, pin12,	T.18	EBIS HV current
AI NI9205, slot1, pin13,	T.19	Separator magnet voltage
AI NI9205, slot1, pin14,	T.20	Separator magnet current
AI NI9205, slot1, pin15,	T.21	Reserved voltage
AI NI9205, slot1, pin16,	T.22	Reserved current
AI NI9205, slot1, pin17,	T.23	Reserved voltage
AI NI9205, slot1, pin18,	T.24	Reserved current
AI NI9205, slot1, pin30,	T.25	Lens ion source line voltage
AI NI9205, slot1, pin31,	T.26	Ion source focussing voltage
AI NI9205, slot1, pin32,	T.27	Gridded lens ToF voltage
AI NI9205, slot1, pin33,	T.28	Einzel lens RFQ voltage
AI NI9205, slot1, pin34,	T.29	Wien filter voltage
AI NI9205, slot1, pin35,	T.30	Gridded lens RFQ voltage
AI NI9205, slot1, pin36,	T.31	Reserved voltage
AI NI9205, slot1, pin37,	T.32	Reserved voltage
AI NI9205, slot1, pin9,	NC	
AI NI9205, slot1, pin10,	T.34	
AI NI9205, slot1, pin28,	NC	
AI NI9205, slot1, pin29,	NC	
AI NI9205, slot1, pin19,	T.35	Analog In Common

Connection Diagram for the Analog Output Module 1

Information

cRIO: ext. line psu
Perspective: Analog Outputs are in ascending order

Definitions

T.x = Top Screw Terminal

cRIO Connection Info	Patch Panel: Top	End Device
AO NI9264, slot2, pin1,	T.36	Vertical deflector RFQ up voltage
AO NI9264, slot2, pin2,	T.37	Vertical deflector RFQ down voltage
AO NI9264, slot2, pin3,	T.38	Horizontal deflector RFQ left voltage
AO NI9264, slot2, pin4,	T.39	Horizontal deflector RFQ right voltage
AO NI9264, slot2, pin5,	T.40	Vertical deflector ion 1 up voltage
AO NI9264, slot2, pin6,	T.41	Vertical deflector ion 1 down voltage
AO NI9264, slot2, pin7,	T.42	Horizontal deflector ion 1 left voltage
AO NI9264, slot2, pin8,	T.43	Horizontal deflector ion 1 right voltage
AO NI9264, slot2, pin11,	T.44	Vertical deflector ion 2 up voltage
AO NI9264, slot2, pin12,	T.45	Vertical deflector ion 2 down voltage
AO NI9264, slot2, pin13,	T.46	Horizontal deflector ion 2 left voltage
AO NI9264, slot2, pin14,	T.47	Horizontal deflector ion 2 right voltage
AO NI9264, slot2, pin15,	T.48	Vertical deflector ion 3 up voltage
AO NI9264, slot2, pin16,	T.49	Vertical deflector ion 3 down voltage
AO NI9264, slot2, pin17,	T.50	Horizontal deflector ion 3 left voltage
AO NI9264, slot2, pin18,	T.51	Horizontal deflector ion 3 right voltage
AO NI9264, slot2, pin19,	T.69	Analog Out Common Ground
AO NI9264, slot2, pin20,	NC	
AO NI9264, slot2, pin21,	NC	
AO NI9264, slot2, pin22,	NC	
AO NI9264, slot2, pin23,	NC	
AO NI9264, slot2, pin24,	NC	
AO NI9264, slot2, pin25,	NC	
AO NI9264, slot2, pin26,	NC	
AO NI9264, slot2, pin27,	NC	
AO NI9264, slot2, pin30,	NC	
AO NI9264, slot2, pin31,	NC	
AO NI9264, slot2, pin32,	NC	
AO NI9264, slot2, pin33,	NC	
AO NI9264, slot2, pin34,	NC	
AO NI9264, slot2, pin35,	NC	
AO NI9264, slot2, pin36,	NC	
AO NI9264, slot2, pin37,	NC	
AO NI9264, slot2, pin9,	NC	
AO NI9264, slot2, pin10,	NC	
AO NI9264, slot2, pin28,	NC	
AO NI9264, slot2, pin29,	NC	

Connection Diagram for the Analog Output Module 2

Information

cRIO: ext. line psu
Perspective: Analog Outputs are in ascending order

Definitions

T.x = Top Screw Terminal

cRIO Connection Info	Patch Panel: Top	End Device
AO NI9264, slot3, pin1,	T.52	EBIS HV
AO NI9264, slot3, pin2,	T.53	EBIS HV current
AO NI9264, slot3, pin3,	T.54	Separator magnet voltage
AO NI9264, slot3, pin4,	T.55	Separator magnet current
AO NI9264, slot3, pin5,	T.56	Reserved voltage
AO NI9264, slot3, pin6,	T.57	Reserved current
AO NI9264, slot3, pin7,	T.58	Reserved voltage
AO NI9264, slot3, pin8,	T.59	Reserved current
AO NI9264, slot3, pin11,	T.60	Lens ion source line voltage
AO NI9264, slot3, pin12,	T.61	Ion source focussing voltage
AO NI9264, slot3, pin13,	T.62	Gridded lens ToF voltage
AO NI9264, slot3, pin14,	T.63	Einzel lens RFQ voltage
AO NI9264, slot3, pin15,	T.64	Wien filter voltage
AO NI9264, slot3, pin16,	T.65	Gridded lens RFQ voltage
AO NI9264, slot3, pin17,	T.66	Reserved voltage
AO NI9264, slot3, pin18,	T.67	Reserved voltage
AO NI9264, slot3, pin19,	T.68	Analog Out Common Ground
AO NI9264, slot3, pin20,	NC	
AO NI9264, slot3, pin21,	NC	
AO NI9264, slot3, pin22,	NC	
AO NI9264, slot3, pin23,	NC	
AO NI9264, slot3, pin24,	NC	
AO NI9264, slot3, pin25,	NC	
AO NI9264, slot3, pin26,	NC	
AO NI9264, slot3, pin27,	NC	
AO NI9264, slot3, pin30,	NC	
AO NI9264, slot3, pin31,	NC	
AO NI9264, slot3, pin32,	NC	
AO NI9264, slot3, pin33,	NC	
AO NI9264, slot3, pin34,	NC	
AO NI9264, slot3, pin35,	NC	
AO NI9264, slot3, pin36,	NC	
AO NI9264, slot3, pin37,	NC	
AO NI9264, slot3, pin9,	NC	
AO NI9264, slot3, pin10,	NC	
AO NI9264, slot3, pin28,	NC	
AO NI9264, slot3, pin29,	NC	

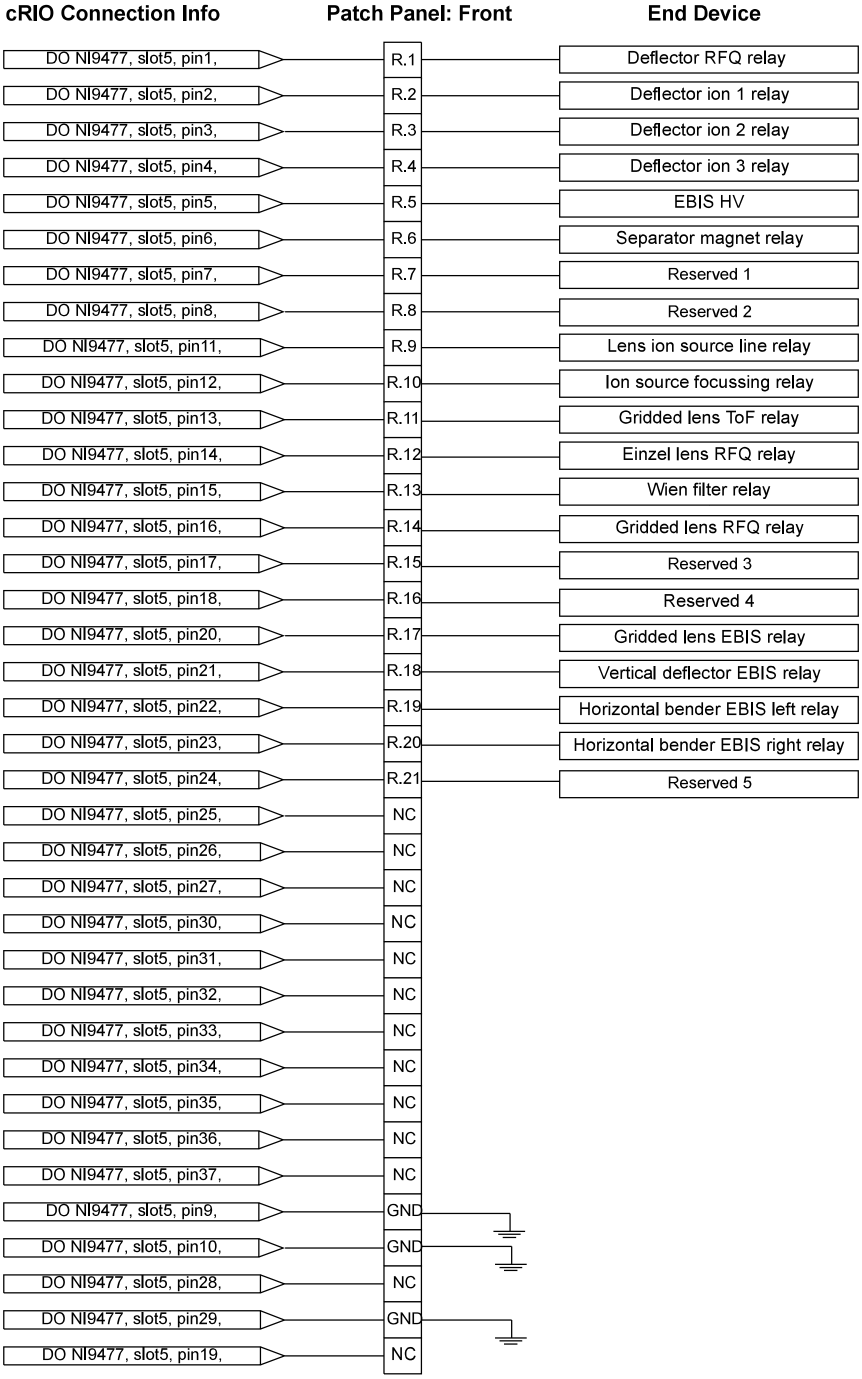
Connection Diagram for the Digital Output Module

Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Digital Output are in ascending order

Definitions

F.x = Front Screw Terminal
R.x = Relay terminal



cRIO Connection Info	Patch Panel: Front	End Device
DO NI9477, slot5, pin1,	R.1	Deflector RFQ relay
DO NI9477, slot5, pin2,	R.2	Deflector ion 1 relay
DO NI9477, slot5, pin3,	R.3	Deflector ion 2 relay
DO NI9477, slot5, pin4,	R.4	Deflector ion 3 relay
DO NI9477, slot5, pin5,	R.5	EBIS HV
DO NI9477, slot5, pin6,	R.6	Separator magnet relay
DO NI9477, slot5, pin7,	R.7	Reserved 1
DO NI9477, slot5, pin8,	R.8	Reserved 2
DO NI9477, slot5, pin11,	R.9	Lens ion source line relay
DO NI9477, slot5, pin12,	R.10	Ion source focussing relay
DO NI9477, slot5, pin13,	R.11	Gridded lens ToF relay
DO NI9477, slot5, pin14,	R.12	Einzel lens RFQ relay
DO NI9477, slot5, pin15,	R.13	Wien filter relay
DO NI9477, slot5, pin16,	R.14	Gridded lens RFQ relay
DO NI9477, slot5, pin17,	R.15	Reserved 3
DO NI9477, slot5, pin18,	R.16	Reserved 4
DO NI9477, slot5, pin20,	R.17	Gridded lens EBIS relay
DO NI9477, slot5, pin21,	R.18	Vertical deflector EBIS relay
DO NI9477, slot5, pin22,	R.19	Horizontal bender EBIS left relay
DO NI9477, slot5, pin23,	R.20	Horizontal bender EBIS right relay
DO NI9477, slot5, pin24,	R.21	Reserved 5
DO NI9477, slot5, pin25,	NC	
DO NI9477, slot5, pin26,	NC	
DO NI9477, slot5, pin27,	NC	
DO NI9477, slot5, pin30,	NC	
DO NI9477, slot5, pin31,	NC	
DO NI9477, slot5, pin32,	NC	
DO NI9477, slot5, pin33,	NC	
DO NI9477, slot5, pin34,	NC	
DO NI9477, slot5, pin35,	NC	
DO NI9477, slot5, pin36,	NC	
DO NI9477, slot5, pin37,	NC	
DO NI9477, slot5, pin9,	GND	
DO NI9477, slot5, pin10,	GND	
DO NI9477, slot5, pin28,	NC	
DO NI9477, slot5, pin29,	GND	
DO NI9477, slot5, pin19,	NC	

Connection Diagram for the TTL Module

Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: TTLs are in ascending order

Definitions

B.x = Bottom Screw Terminal

cRIO Connection Info	Patch Panel: Front	End Device
TTL NI9403, slot8, pin1,	B.1	Vertical deflector RFQ up polarity shift
TTL NI9403, slot8, pin2,	B.2	Vertical deflector RFQ down polarity shift
TTL NI9403, slot8, pin3,	B.3	Horizontal deflector RFQ left polarity shift
TTL NI9403, slot8, pin4,	B.4	Horizontal deflector RFQ right polarity shift
TTL NI9403, slot8, pin5,	B.5	Vertical deflector ion 1 up polarity shift
TTL NI9403, slot8, pin6,	B.6	Vertical deflector ion 1 down polarity shift
TTL NI9403, slot8, pin7,	B.7	Horizontal deflector ion 1 left polarity shift
TTL NI9403, slot8, pin8,	B.8	Horizontal deflector ion 1 right polarity shift
TTL NI9403, slot8, pin11,	B.9	Vertical deflector ion 2 up polarity shift
TTL NI9403, slot8, pin12,	B.10	Vertical deflector ion 2 down polarity shift
TTL NI9403, slot8, pin13,	B.11	Horizontal deflector ion 2 left polarity shift
TTL NI9403, slot8, pin14,	B.12	Horizontal deflector ion 2 right polarity shift
TTL NI9403, slot8, pin15,	B.13	Vertical deflector ion 3 up polarity shift
TTL NI9403, slot8, pin16,	B.14	Vertical deflector ion 3 down polarity shift
TTL NI9403, slot8, pin17,	B.15	Horizontal deflector ion 3 left polarity shift
TTL NI9403, slot8, pin18,	B.16	Horizontal deflector ion 3 right polarity shift
TTL NI9403, slot8, pin20,	B.17	
TTL NI9403, slot8, pin21,	B.18	
TTL NI9403, slot8, pin22,	B.19	
TTL NI9403, slot8, pin23,	B.20	
TTL NI9403, slot8, pin24,	B.21	
TTL NI9403, slot8, pin25,	B.22	
TTL NI9403, slot8, pin26,	B.23	
TTL NI9403, slot8, pin27,	B.24	
TTL NI9403, slot8, pin30,	B.25	
TTL NI9403, slot8, pin31,	B.26	
TTL NI9403, slot8, pin32,	B.27	
TTL NI9403, slot8, pin33,	B.28	
TTL NI9403, slot8, pin34,	B.29	
TTL NI9403, slot8, pin35,	B.30	
TTL NI9403, slot8, pin36,	B.31	
TTL NI9403, slot8, pin37,	B.32	
TTL NI9403, slot8, pin9,	B.33	⏚
TTL NI9403, slot8, pin10,	B.34	
TTL NI9403, slot8, pin28,	NC	
TTL NI9403, slot8, pin29,	NC	
TTL NI9403, slot8, pin19,	NC	

Connection Diagram for the backplane of the box

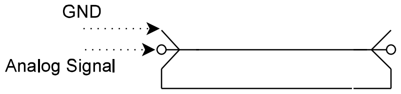
Information

cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Back panel Connectors are in ascending order

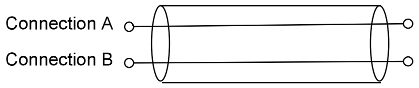
Definitions

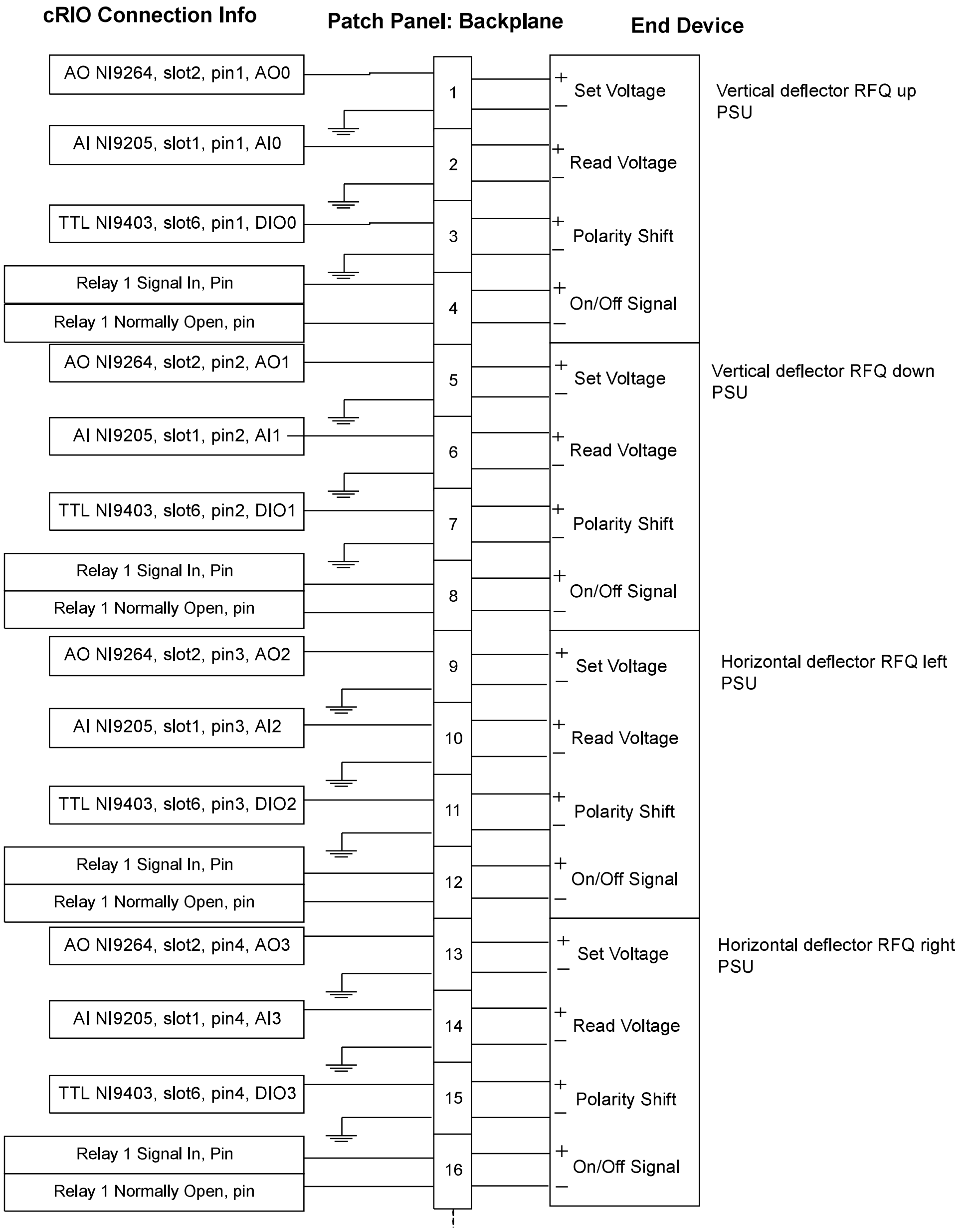
B.x = Top Screw Terminal
GND = Ground
xx-x = Berndi_connector-berndie_pin

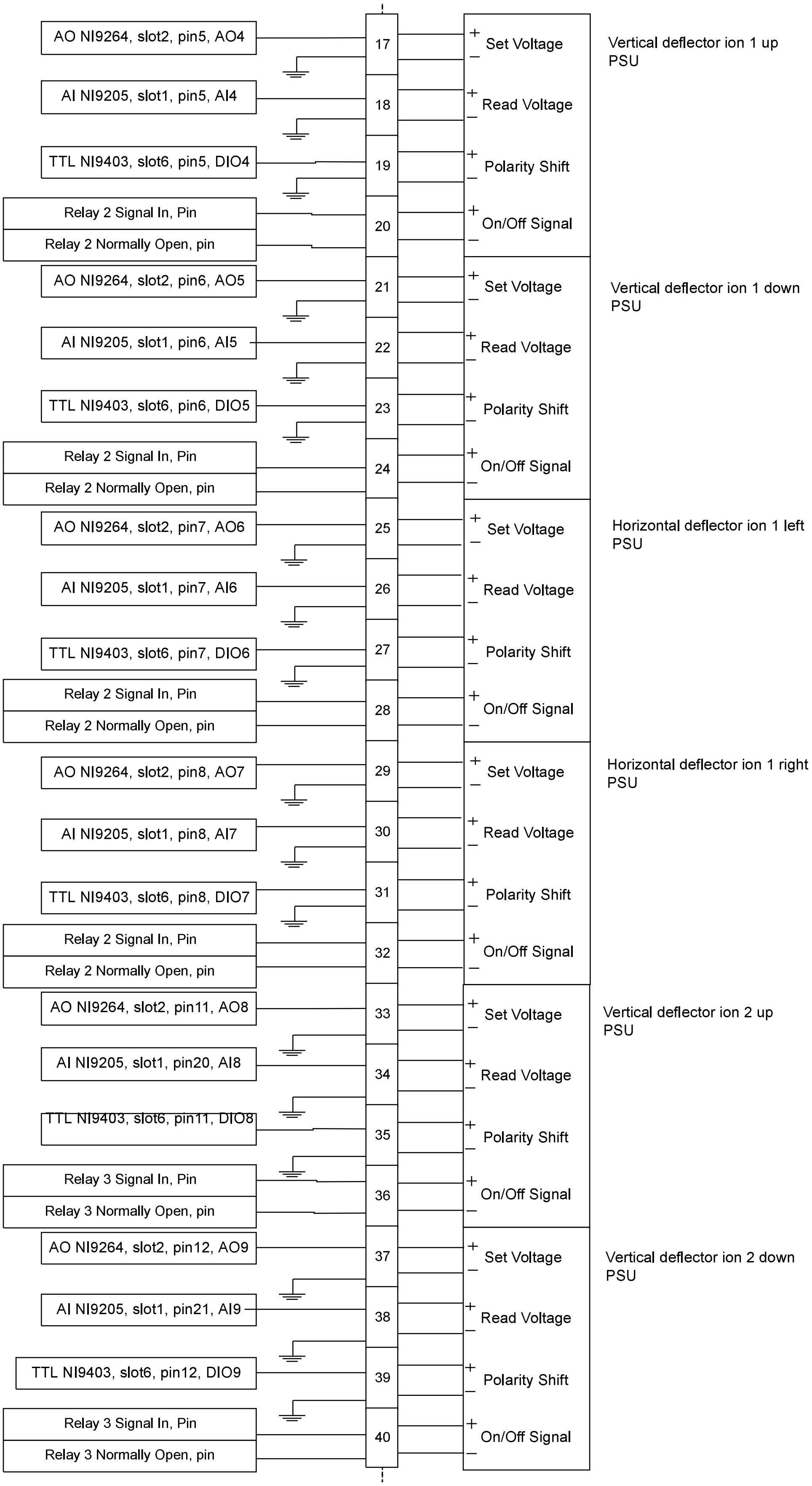
Most LEMOs are 00 and are connect and wired like this.

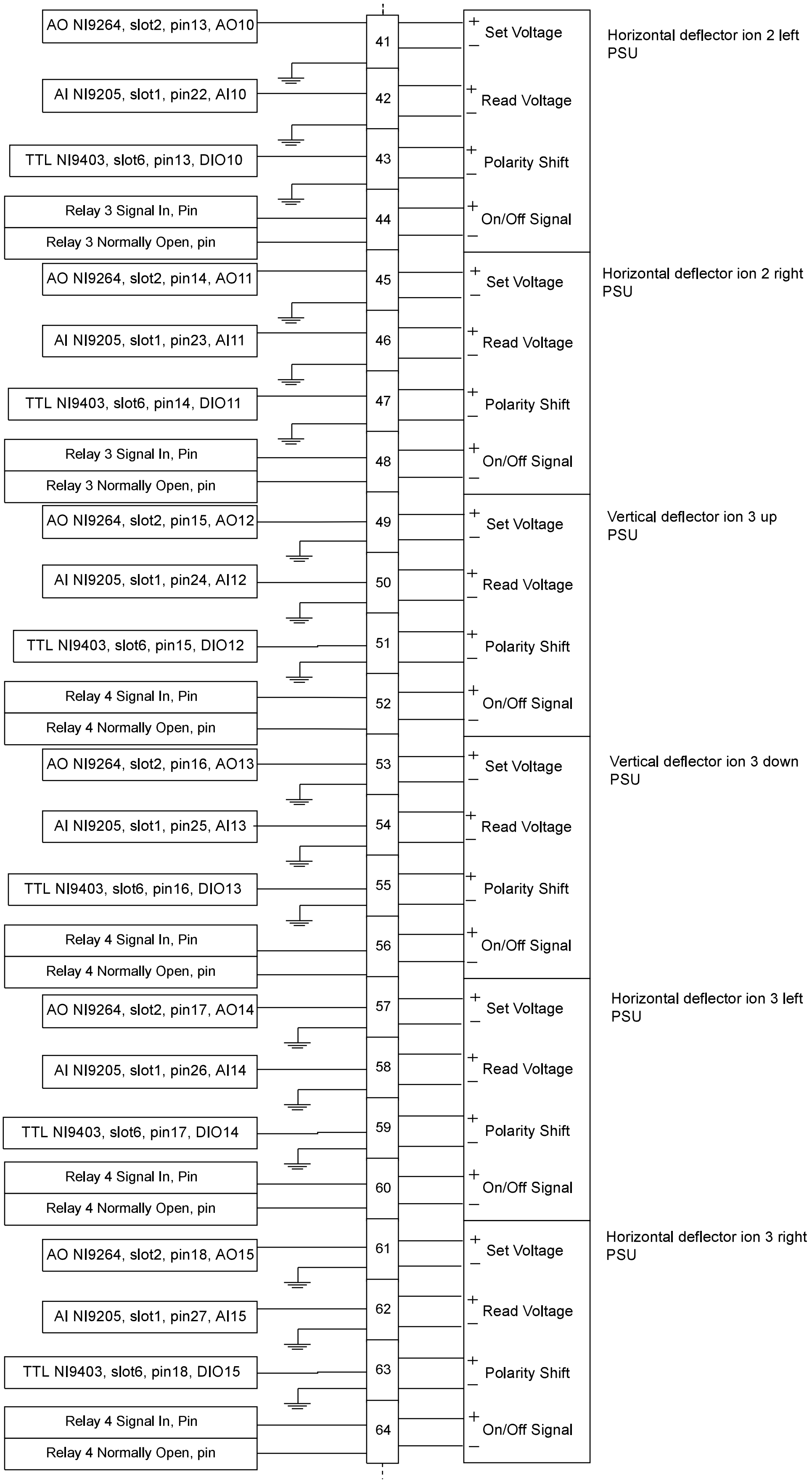


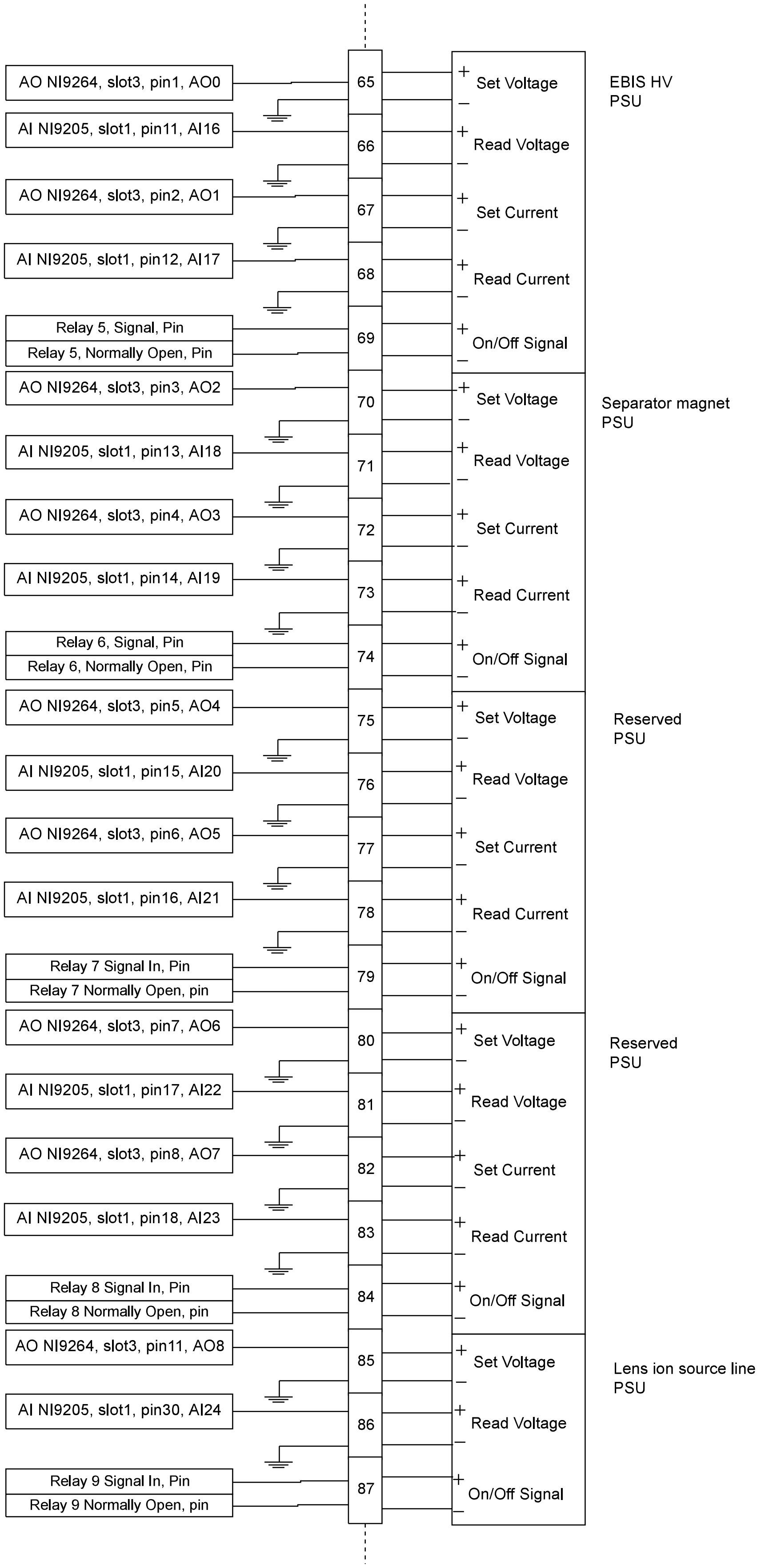
The relay uses LEMO 2 and has this type of connection and wiring

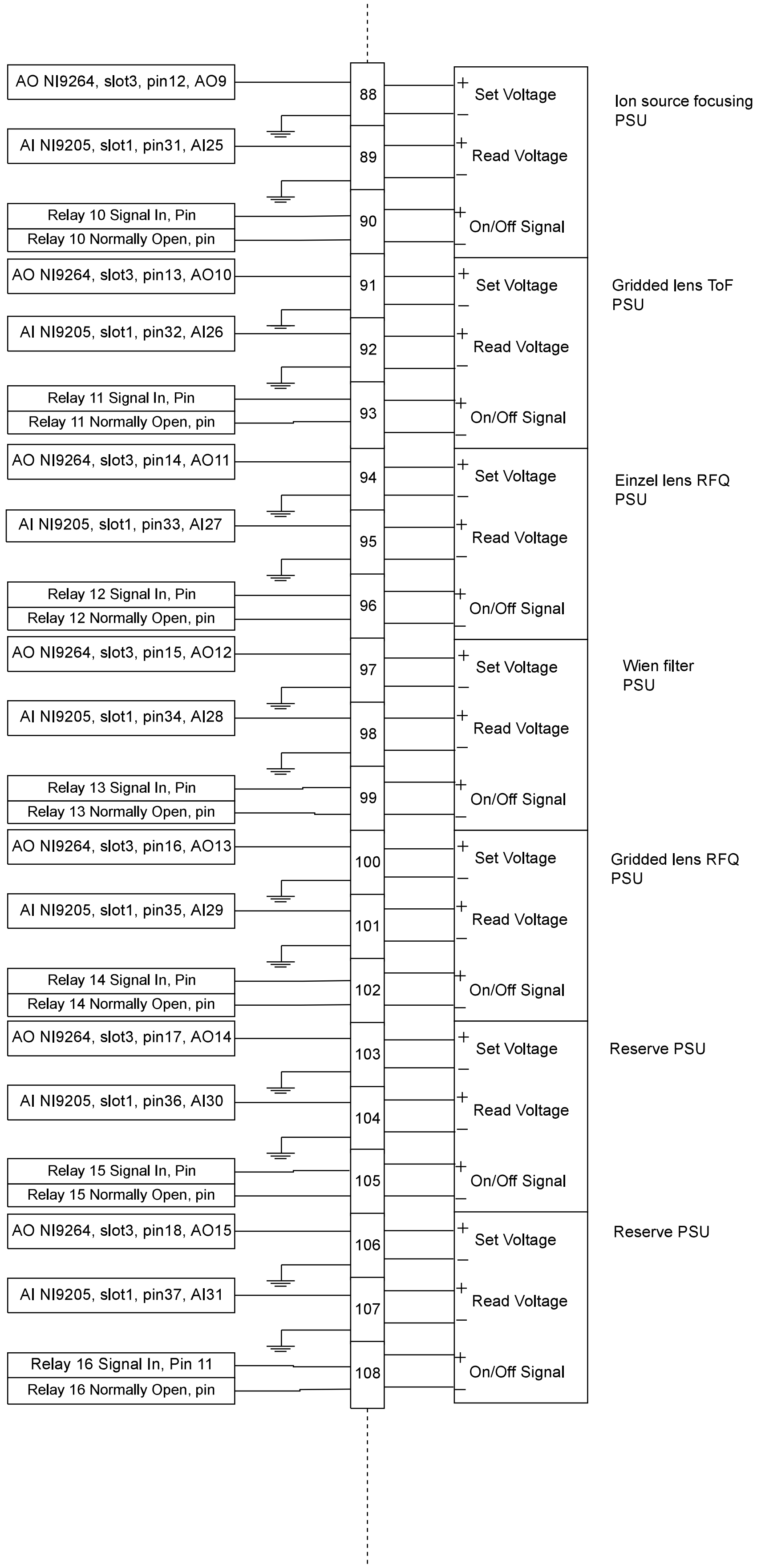


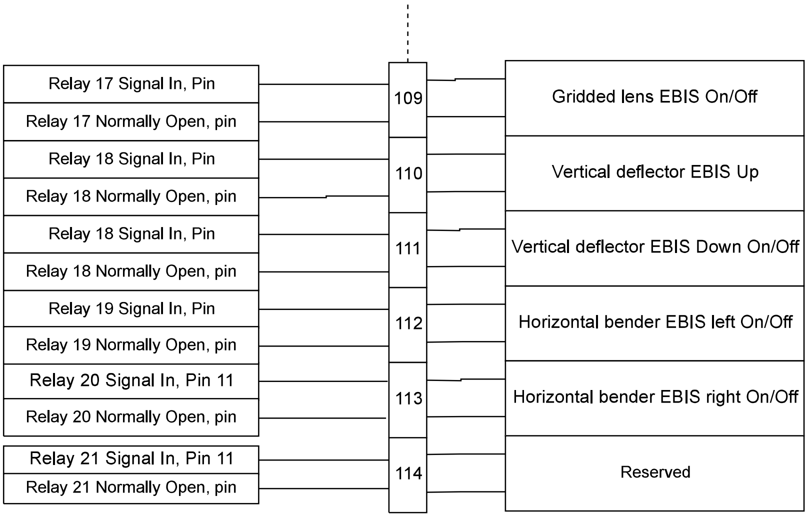



AO NI9264, slot2, pin5, AO4
AI NI9205, slot1, pin5, AI4
TTL NI9403, slot6, pin5, DIO4
Relay 2 Signal In, Pin
Relay 2 Normally Open, pin
AO NI9264, slot2, pin6, AO5
AI NI9205, slot1, pin6, AI5
TTL NI9403, slot6, pin6, DIO5
Relay 2 Signal In, Pin
Relay 2 Normally Open, pin
AO NI9264, slot2, pin7, AO6
AI NI9205, slot1, pin7, AI6
TTL NI9403, slot6, pin7, DIO6
Relay 2 Signal In, Pin
Relay 2 Normally Open, pin
AO NI9264, slot2, pin8, AO7
AI NI9205, slot1, pin8, AI7
TTL NI9403, slot6, pin8, DIO7
Relay 2 Signal In, Pin
Relay 2 Normally Open, pin
AO NI9264, slot2, pin11, AO8
AI NI9205, slot1, pin20, AI8
TTL NI9403, slot6, pin11, DIO8
Relay 3 Signal In, Pin
Relay 3 Normally Open, pin
AO NI9264, slot2, pin12, AO9
AI NI9205, slot1, pin21, AI9
TTL NI9403, slot6, pin12, DIO9
Relay 3 Signal In, Pin
Relay 3 Normally Open, pin
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Vertical deflector ion 1 up PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Vertical deflector ion 1 down PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Horizontal deflector ion 1 left PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Horizontal deflector ion 1 right PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Vertical deflector ion 2 up PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Vertical deflector ion 2 down PSU


AO NI9264, slot2, pin13, AO10
AI NI9205, slot1, pin22, AI10
TTL NI9403, slot6, pin13, DIO10
Relay 3 Signal In, Pin
Relay 3 Normally Open, pin
AO NI9264, slot2, pin14, AO11
AI NI9205, slot1, pin23, AI11
TTL NI9403, slot6, pin14, DIO11
Relay 3 Signal In, Pin
Relay 3 Normally Open, pin
AO NI9264, slot2, pin15, AO12
AI NI9205, slot1, pin24, AI12
TTL NI9403, slot6, pin15, DIO12
Relay 4 Signal In, Pin
Relay 4 Normally Open, pin
AO NI9264, slot2, pin16, AO13
AI NI9205, slot1, pin25, AI13
TTL NI9403, slot6, pin16, DIO13
Relay 4 Signal In, Pin
Relay 4 Normally Open, pin
AO NI9264, slot2, pin17, AO14
AI NI9205, slot1, pin26, AI14
TTL NI9403, slot6, pin17, DIO14
Relay 4 Signal In, Pin
Relay 4 Normally Open, pin
AO NI9264, slot2, pin18, AO15
AI NI9205, slot1, pin27, AI15
TTL NI9403, slot6, pin18, DIO15
Relay 4 Signal In, Pin
Relay 4 Normally Open, pin
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Horizontal deflector ion 2 left PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Horizontal deflector ion 2 right PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Vertical deflector ion 3 up PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Vertical deflector ion 3 down PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Horizontal deflector ion 3 left PSU
+ Set Voltage –
+ Read Voltage –
+ Polarity Shift –
+ On/Off Signal –
Horizontal deflector ion 3 right PSU


AO NI9264, slot3, pin1, AO0
AI NI9205, slot1, pin11, AI16
AO NI9264, slot3, pin2, AO1
AI NI9205, slot1, pin12, AI17
Relay 5, Signal, Pin
Relay 5, Normally Open, Pin
AO NI9264, slot3, pin3, AO2
AI NI9205, slot1, pin13, AI18
AO NI9264, slot3, pin4, AO3
AI NI9205, slot1, pin14, AI19
Relay 6, Signal, Pin
Relay 6, Normally Open, Pin
AO NI9264, slot3, pin5, AO4
AI NI9205, slot1, pin15, AI20
AO NI9264, slot3, pin6, AO5
AI NI9205, slot1, pin16, AI21
Relay 7 Signal In, Pin
Relay 7 Normally Open, pin
AO NI9264, slot3, pin7, AO6
AI NI9205, slot1, pin17, AI22
AO NI9264, slot3, pin8, AO7
AI NI9205, slot1, pin18, AI23
Relay 8 Signal In, Pin
Relay 8 Normally Open, pin
AO NI9264, slot3, pin11, AO8
AI NI9205, slot1, pin30, AI24
Relay 9 Signal In, Pin
Relay 9 Normally Open, pin
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
Set Voltage
Read Voltage
Set Current
Read Current
On/Off Signal
EBIS HV PSU
Set Voltage
Read Voltage
Set Current
Read Current
On/Off Signal
Separator magnet PSU
Set Voltage
Read Voltage
Set Current
Read Current
On/Off Signal
Reserved PSU
Set Voltage
Read Voltage
Set Current
Read Current
On/Off Signal
Reserved PSU
Set Voltage
Read Voltage
On/Off Signal
Lens ion source line PSU
+
−

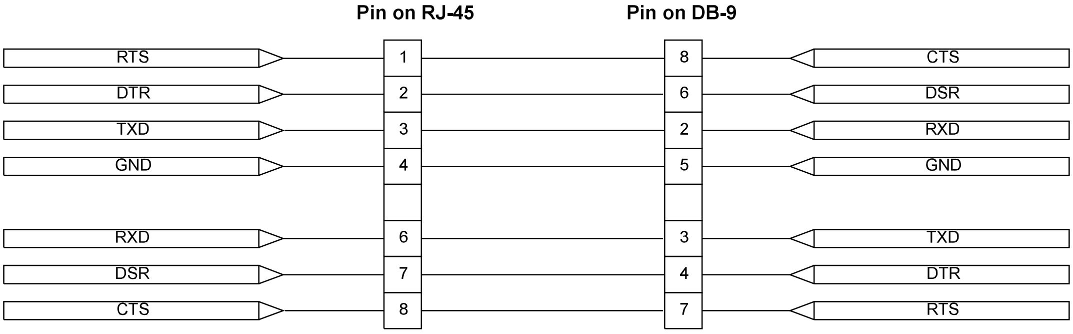

AO NI9264, slot3, pin12, AO9
AI NI9205, slot1, pin31, AI25
Relay 10 Signal In, Pin
Relay 10 Normally Open, pin
AO NI9264, slot3, pin13, AO10
AI NI9205, slot1, pin32, AI26
Relay 11 Signal In, Pin
Relay 11 Normally Open, pin
AO NI9264, slot3, pin14, AO11
AI NI9205, slot1, pin33, AI27
Relay 12 Signal In, Pin
Relay 12 Normally Open, pin
AO NI9264, slot3, pin15, AO12
AI NI9205, slot1, pin34, AI28
Relay 13 Signal In, Pin
Relay 13 Normally Open, pin
AO NI9264, slot3, pin16, AO13
AI NI9205, slot1, pin35, AI29
Relay 14 Signal In, Pin
Relay 14 Normally Open, pin
AO NI9264, slot3, pin17, AO14
AI NI9205, slot1, pin36, AI30
Relay 15 Signal In, Pin
Relay 15 Normally Open, pin
AO NI9264, slot3, pin18, AO15
AI NI9205, slot1, pin37, AI31
Relay 16 Signal In, Pin 11
Relay 16 Normally Open, pin
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
+ Set Voltage –
+ Read Voltage –
+ On/Off Signal –
Ion source focusing PSU
+ Set Voltage –
+ Read Voltage –
+ On/Off Signal –
Gridded lens ToF PSU
+ Set Voltage –
+ Read Voltage –
+ On/Off Signal –
Einzel lens RFQ PSU
+ Set Voltage –
+ Read Voltage –
+ On/Off Signal –
Wien filter PSU
+ Set Voltage –
+ Read Voltage –
+ On/Off Signal –
Gridded lens RFQ PSU
+ Set Voltage –
+ Read Voltage –
+ On/Off Signal –
Reserve PSU
+ Set Voltage –
+ Read Voltage –
+ On/Off Signal –
Reserve PSU


Relay 17 Signal In, Pin
Relay 17 Normally Open, pin
Relay 18 Signal In, Pin
Relay 18 Normally Open, pin
Relay 18 Signal In, Pin
Relay 18 Normally Open, pin
Relay 19 Signal In, Pin
Relay 19 Normally Open, pin
Relay 20 Signal In, Pin 11
Relay 20 Normally Open, pin
Relay 21 Signal In, Pin 11
Relay 21 Normally Open, pin
109
110
111
112
113
114
Gridded lens EBIS On/Off
Vertical deflector EBIS Up
Vertical deflector EBIS Down On/Off
Horizontal bender EBIS left On/Off
Horizontal bender EBIS right On/Off
Reserved

Serial-communication Extention from cRIO-Chassie to the backplane

The wiring from the RJ-45 to the D-SUB 9 connection on the backplane for RS-232 and RS-485.
They both use the same cable so the diagram counts for both.

RS-232 and RS-485
RJ-45 to D-SUB 9



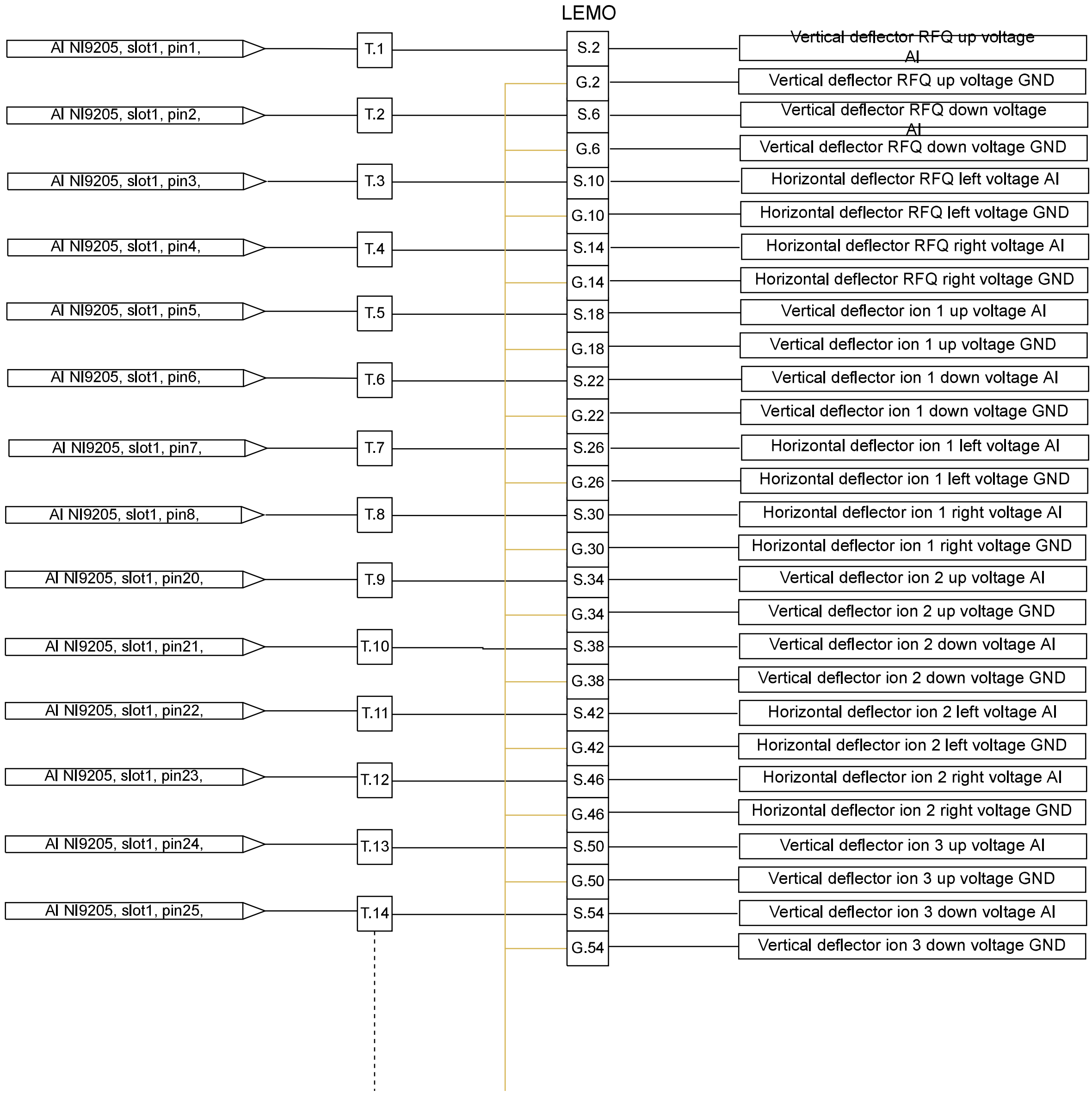
Connection diagram for the Top Screw Terminal

Information

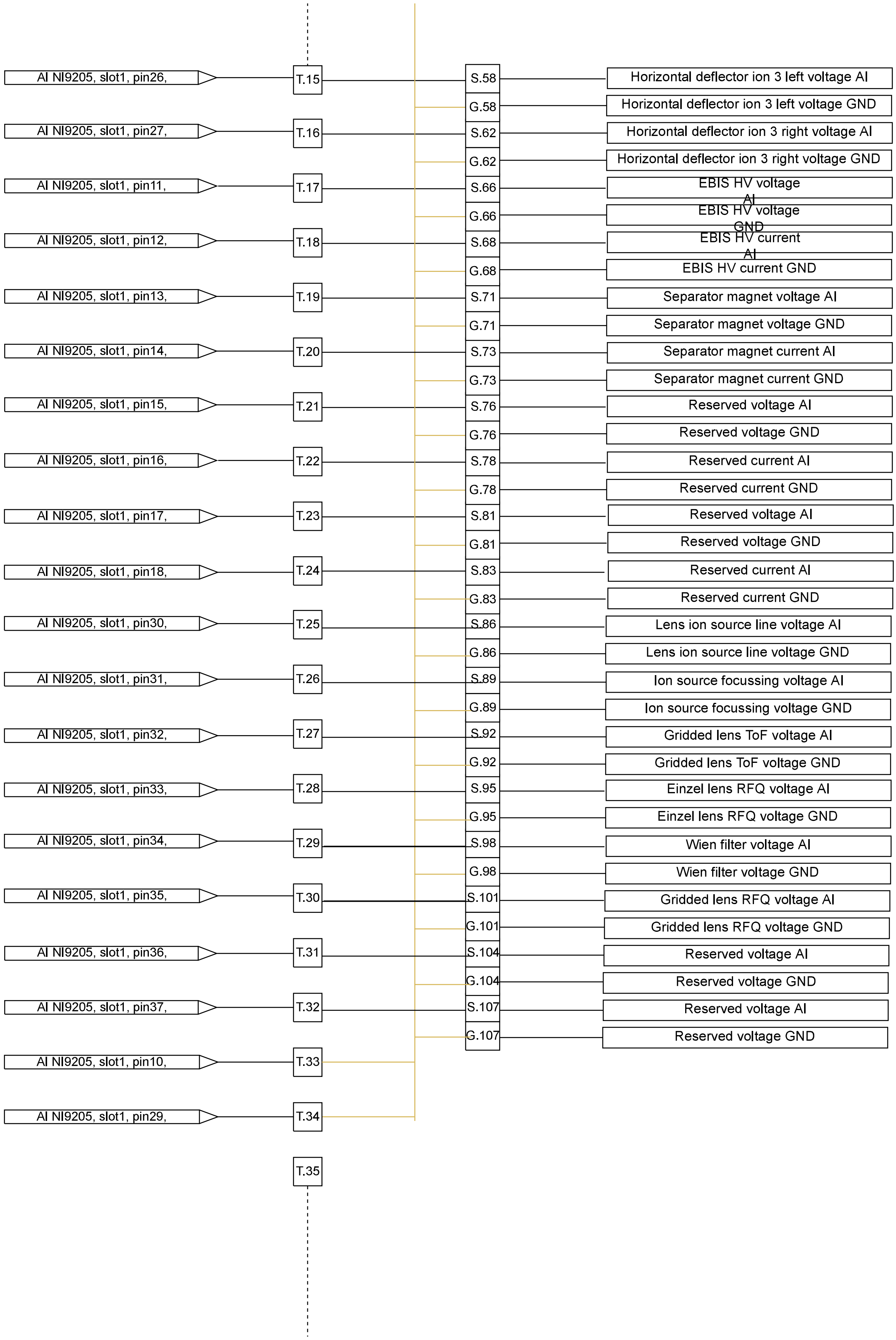
Platform: vacuum water beam
Order: Screw terminal are in ascending order

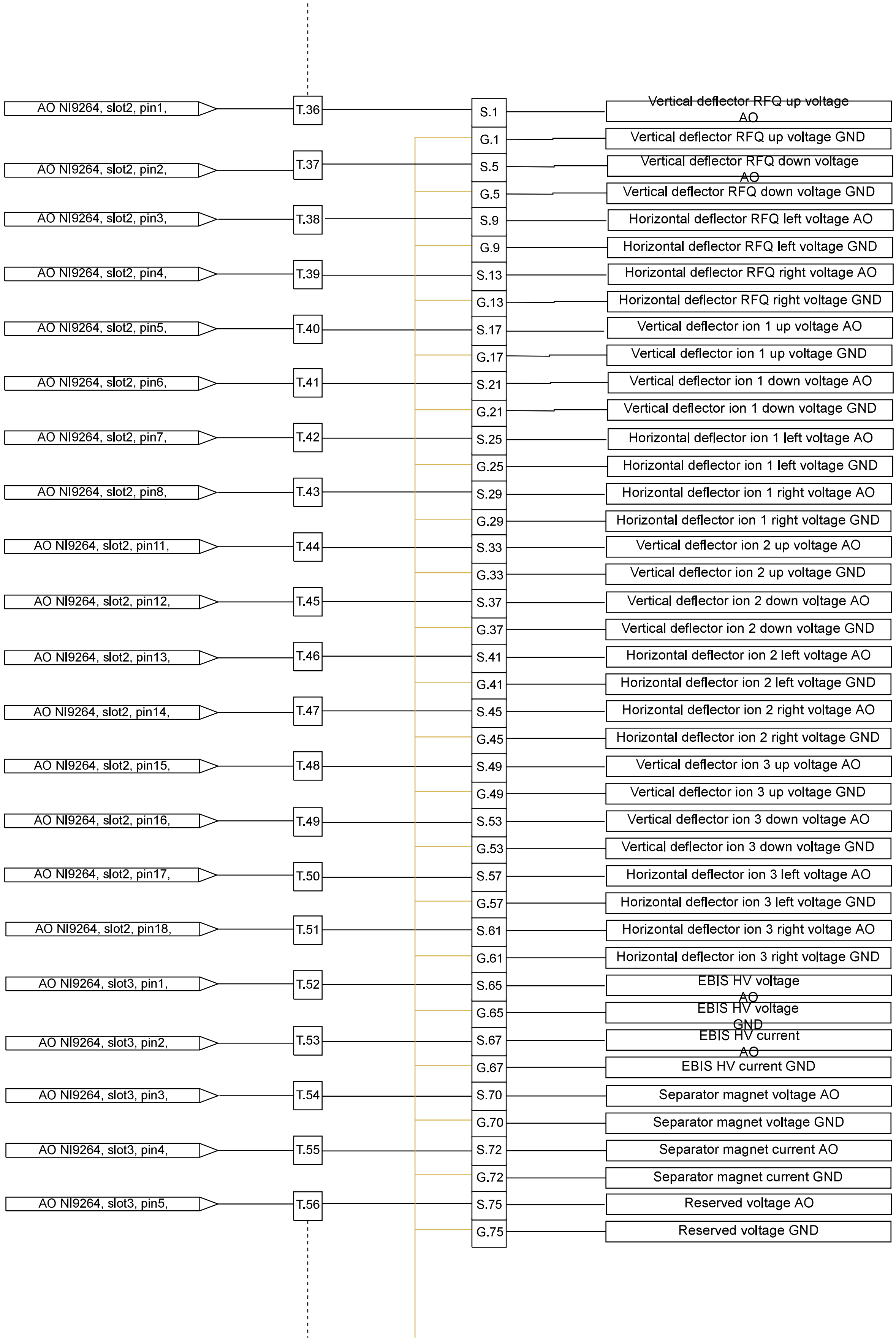
Definitions

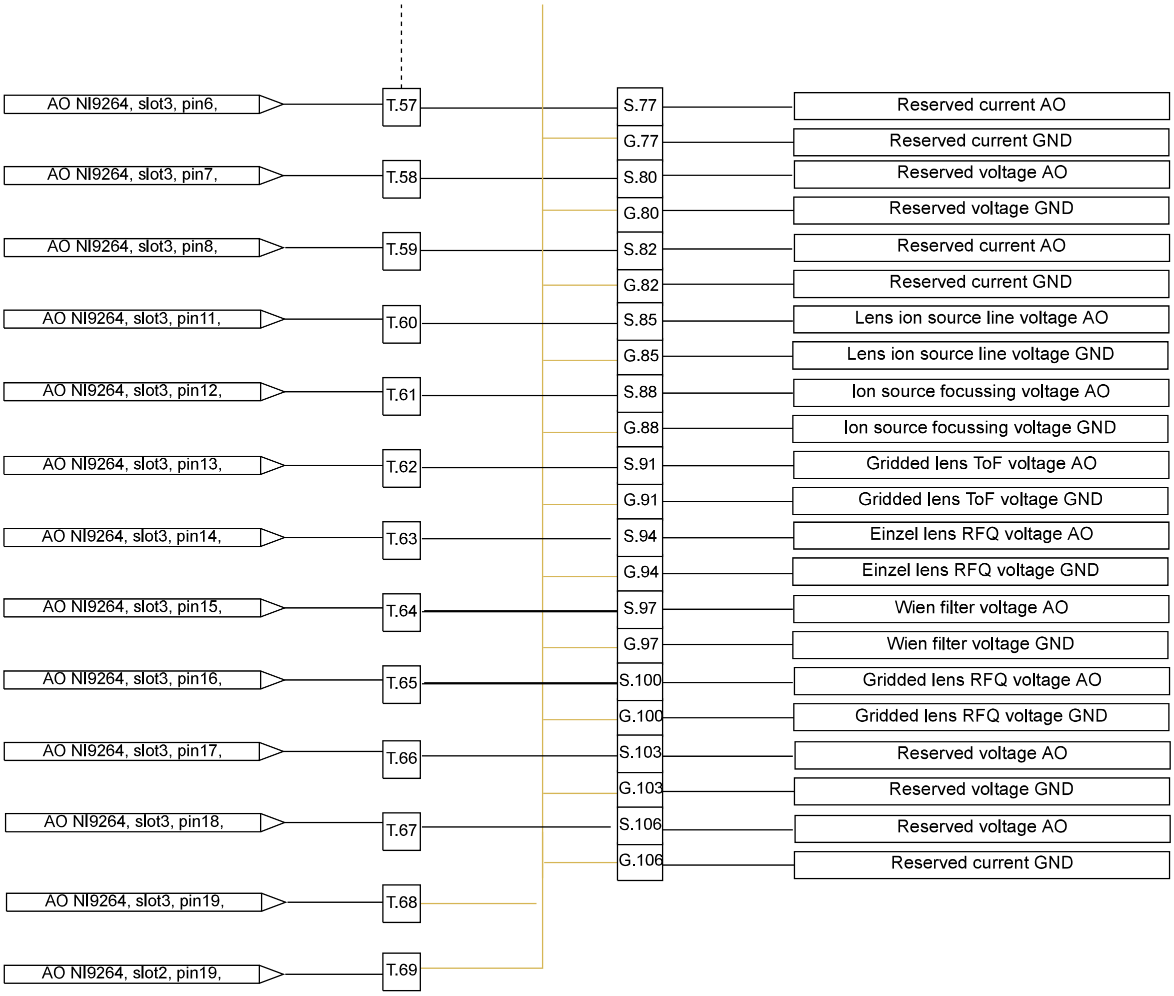
T.x = Top Screw Terminal
S.x = Signal from LEMO connector x
G.x = Ground from LEMO connector x
AI = Analog In
AO = Analog Out
GND = Ground



cRIO Connection Info	Patch Panel: Top	Patch Panel: Back Plate LEMO	End Device
AI NI9205, slot1, pin1,	T.1	S.2	Vertical deflector RFQ up voltage AI
		G.2	Vertical deflector RFQ up voltage GND
AI NI9205, slot1, pin2,	T.2	S.6	Vertical deflector RFQ down voltage AI
		G.6	Vertical deflector RFQ down voltage GND
AI NI9205, slot1, pin3,	T.3	S.10	Horizontal deflector RFQ left voltage AI
		G.10	Horizontal deflector RFQ left voltage GND
AI NI9205, slot1, pin4,	T.4	S.14	Horizontal deflector RFQ right voltage AI
		G.14	Horizontal deflector RFQ right voltage GND
AI NI9205, slot1, pin5,	T.5	S.18	Vertical deflector ion 1 up voltage AI
		G.18	Vertical deflector ion 1 up voltage GND
AI NI9205, slot1, pin6,	T.6	S.22	Vertical deflector ion 1 down voltage AI
		G.22	Vertical deflector ion 1 down voltage GND
AI NI9205, slot1, pin7,	T.7	S.26	Horizontal deflector ion 1 left voltage AI
		G.26	Horizontal deflector ion 1 left voltage GND
AI NI9205, slot1, pin8,	T.8	S.30	Horizontal deflector ion 1 right voltage AI
		G.30	Horizontal deflector ion 1 right voltage GND
AI NI9205, slot1, pin20,	T.9	S.34	Vertical deflector ion 2 up voltage AI
		G.34	Vertical deflector ion 2 up voltage GND
AI NI9205, slot1, pin21,	T.10	S.38	Vertical deflector ion 2 down voltage AI
		G.38	Vertical deflector ion 2 down voltage GND
AI NI9205, slot1, pin22,	T.11	S.42	Horizontal deflector ion 2 left voltage AI
		G.42	Horizontal deflector ion 2 left voltage GND
AI NI9205, slot1, pin23,	T.12	S.46	Horizontal deflector ion 2 right voltage AI
		G.46	Horizontal deflector ion 2 right voltage GND
AI NI9205, slot1, pin24,	T.13	S.50	Vertical deflector ion 3 up voltage AI
		G.50	Vertical deflector ion 3 up voltage GND
AI NI9205, slot1, pin25,	T.14	S.54	Vertical deflector ion 3 down voltage AI
		G.54	Vertical deflector ion 3 down voltage GND


AI NI9205, slot1, pin26,
T.15
S.58
Horizontal deflector ion 3 left voltage AI
G.58
Horizontal deflector ion 3 left voltage GND
AI NI9205, slot1, pin27,
T.16
S.62
Horizontal deflector ion 3 right voltage AI
G.62
Horizontal deflector ion 3 right voltage GND
AI NI9205, slot1, pin11,
T.17
S.66
EBIS HV voltage AI
G.66
EBIS HV voltage GND
AI NI9205, slot1, pin12,
T.18
S.68
EBIS HV current AI
G.68
EBIS HV current GND
AI NI9205, slot1, pin13,
T.19
S.71
Separator magnet voltage AI
G.71
Separator magnet voltage GND
AI NI9205, slot1, pin14,
T.20
S.73
Separator magnet current AI
G.73
Separator magnet current GND
AI NI9205, slot1, pin15,
T.21
S.76
Reserved voltage AI
G.76
Reserved voltage GND
AI NI9205, slot1, pin16,
T.22
S.78
Reserved current AI
G.78
Reserved current GND
AI NI9205, slot1, pin17,
T.23
S.81
Reserved voltage AI
G.81
Reserved voltage GND
AI NI9205, slot1, pin18,
T.24
S.83
Reserved current AI
G.83
Reserved current GND
AI NI9205, slot1, pin30,
T.25
S.86
Lens ion source line voltage AI
G.86
Lens ion source line voltage GND
AI NI9205, slot1, pin31,
T.26
S.89
Ion source focussing voltage AI
G.89
Ion source focussing voltage GND
AI NI9205, slot1, pin32,
T.27
S.92
Gridded lens ToF voltage AI
G.92
Gridded lens ToF voltage GND
AI NI9205, slot1, pin33,
T.28
S.95
Einzel lens RFQ voltage AI
G.95
Einzel lens RFQ voltage GND
AI NI9205, slot1, pin34,
T.29
S.98
Wien filter voltage AI
G.98
Wien filter voltage GND
AI NI9205, slot1, pin35,
T.30
S.101
Gridded lens RFQ voltage AI
G.101
Gridded lens RFQ voltage GND
AI NI9205, slot1, pin36,
T.31
S.104
Reserved voltage AI
G.104
Reserved voltage GND
AI NI9205, slot1, pin37,
T.32
S.107
Reserved voltage AI
G.107
Reserved voltage GND
AI NI9205, slot1, pin10,
T.33
AI NI9205, slot1, pin29,
T.34
T.35


AO NI9264, slot2, pin1,
T.36
S.1
Vertical deflector RFQ up voltage AO
G.1
Vertical deflector RFQ up voltage GND
AO NI9264, slot2, pin2,
T.37
S.5
Vertical deflector RFQ down voltage AO
G.5
Vertical deflector RFQ down voltage GND
AO NI9264, slot2, pin3,
T.38
S.9
Horizontal deflector RFQ left voltage AO
G.9
Horizontal deflector RFQ left voltage GND
AO NI9264, slot2, pin4,
T.39
S.13
Horizontal deflector RFQ right voltage AO
G.13
Horizontal deflector RFQ right voltage GND
AO NI9264, slot2, pin5,
T.40
S.17
Vertical deflector ion 1 up voltage AO
G.17
Vertical deflector ion 1 up voltage GND
AO NI9264, slot2, pin6,
T.41
S.21
Vertical deflector ion 1 down voltage AO
G.21
Vertical deflector ion 1 down voltage GND
AO NI9264, slot2, pin7,
T.42
S.25
Horizontal deflector ion 1 left voltage AO
G.25
Horizontal deflector ion 1 left voltage GND
AO NI9264, slot2, pin8,
T.43
S.29
Horizontal deflector ion 1 right voltage AO
G.29
Horizontal deflector ion 1 right voltage GND
AO NI9264, slot2, pin11,
T.44
S.33
Vertical deflector ion 2 up voltage AO
G.33
Vertical deflector ion 2 up voltage GND
AO NI9264, slot2, pin12,
T.45
S.37
Vertical deflector ion 2 down voltage AO
G.37
Vertical deflector ion 2 down voltage GND
AO NI9264, slot2, pin13,
T.46
S.41
Horizontal deflector ion 2 left voltage AO
G.41
Horizontal deflector ion 2 left voltage GND
AO NI9264, slot2, pin14,
T.47
S.45
Horizontal deflector ion 2 right voltage AO
G.45
Horizontal deflector ion 2 right voltage GND
AO NI9264, slot2, pin15,
T.48
S.49
Vertical deflector ion 3 up voltage AO
G.49
Vertical deflector ion 3 up voltage GND
AO NI9264, slot2, pin16,
T.49
S.53
Vertical deflector ion 3 down voltage AO
G.53
Vertical deflector ion 3 down voltage GND
AO NI9264, slot2, pin17,
T.50
S.57
Horizontal deflector ion 3 left voltage AO
G.57
Horizontal deflector ion 3 left voltage GND
AO NI9264, slot2, pin18,
T.51
S.61
Horizontal deflector ion 3 right voltage AO
G.61
Horizontal deflector ion 3 right voltage GND
AO NI9264, slot3, pin1,
T.52
S.65
EBIS HV voltage AO
G.65
EBIS HV voltage GND
AO NI9264, slot3, pin2,
T.53
S.67
EBIS HV current AO
G.67
EBIS HV current GND
AO NI9264, slot3, pin3,
T.54
S.70
Separator magnet voltage AO
G.70
Separator magnet voltage GND
AO NI9264, slot3, pin4,
T.55
S.72
Separator magnet current AO
G.72
Separator magnet current GND
AO NI9264, slot3, pin5,
T.56
S.75
Reserved voltage AO
G.75
Reserved voltage GND


AO NI9264, slot3, pin6,
T.57
S.77
Reserved current AO
G.77
Reserved current GND
AO NI9264, slot3, pin7,
T.58
S.80
Reserved voltage AO
G.80
Reserved voltage GND
AO NI9264, slot3, pin8,
T.59
S.82
Reserved current AO
G.82
Reserved current GND
AO NI9264, slot3, pin11,
T.60
S.85
Lens ion source line voltage AO
G.85
Lens ion source line voltage GND
AO NI9264, slot3, pin12,
T.61
S.88
Ion source focussing voltage AO
G.88
Ion source focussing voltage GND
AO NI9264, slot3, pin13,
T.62
S.91
Gridded lens ToF voltage AO
G.91
Gridded lens ToF voltage GND
AO NI9264, slot3, pin14,
T.63
S.94
Einzel lens RFQ voltage AO
G.94
Einzel lens RFQ voltage GND
AO NI9264, slot3, pin15,
T.64
S.97
Wien filter voltage AO
G.97
Wien filter voltage GND
AO NI9264, slot3, pin16,
T.65
S.100
Gridded lens RFQ voltage AO
G.100
Gridded lens RFQ voltage GND
AO NI9264, slot3, pin17,
T.66
S.103
Reserved voltage AO
G.103
Reserved voltage GND
AO NI9264, slot3, pin18,
T.67
S.106
Reserved voltage AO
G.106
Reserved current GND
AO NI9264, slot3, pin19,
T.68
AO NI9264, slot2, pin19,
T.69

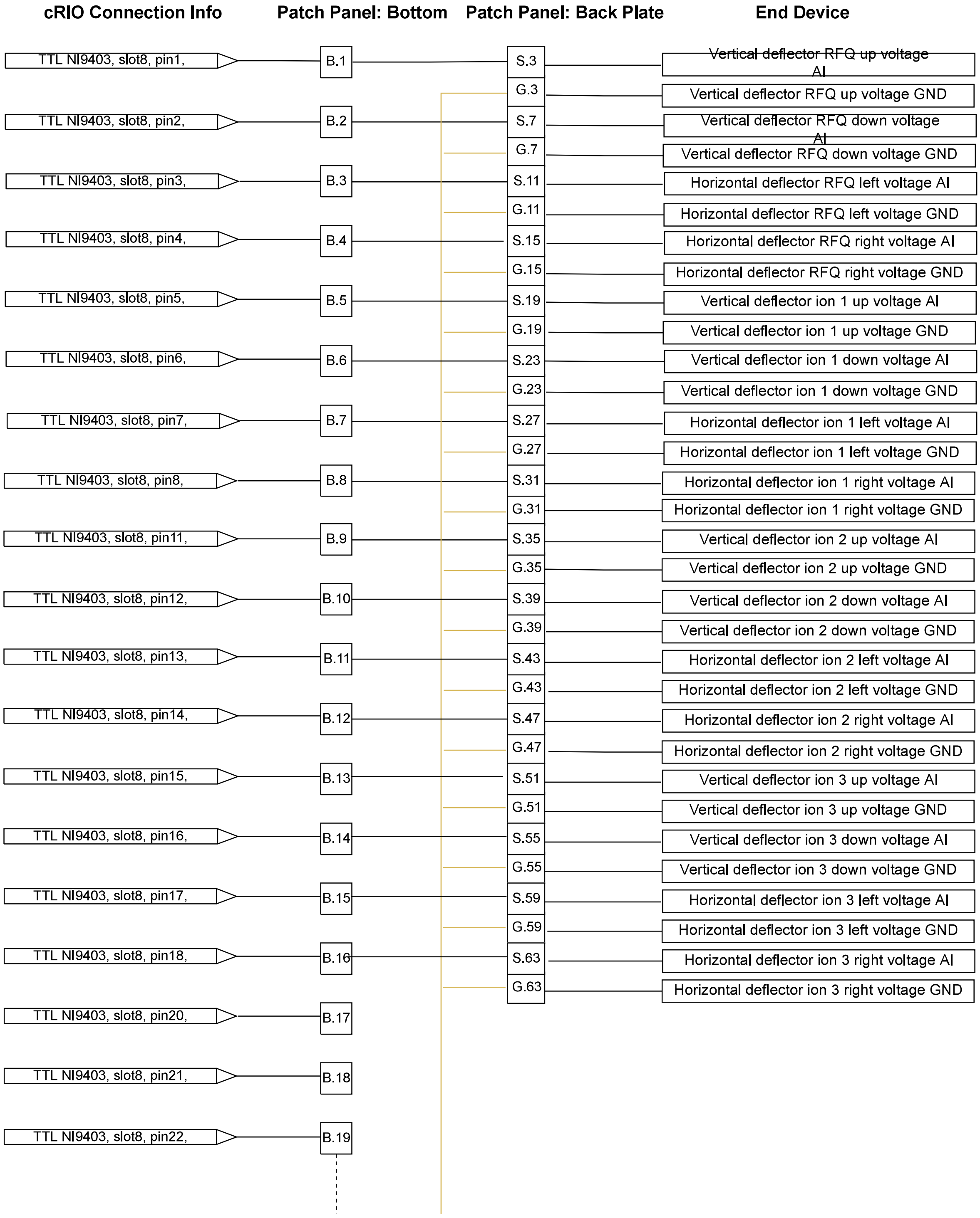
Connection diagram for the Bottom Screw Terminal

Information

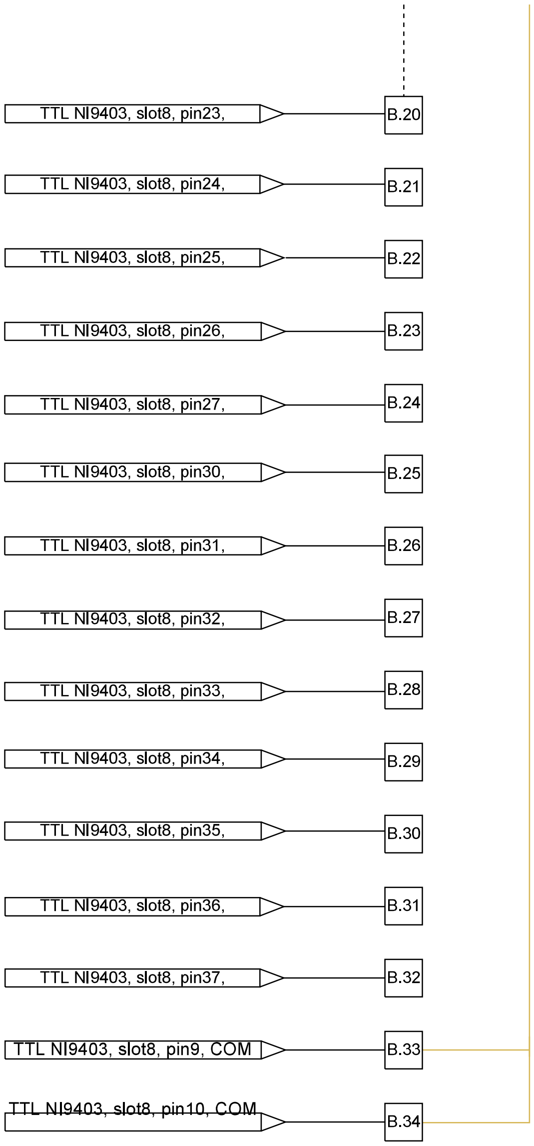
cRIO: ext. line psu
Order: Screw terminal are in ascending order

Definitions

AI = Analog In
AO = Analog Out
B.x = Top Screw Terminal
GND = Ground



cRIO Connection Info	Patch Panel: Bottom	Patch Panel: Back Plate	End Device
TTL NI9403, slot8, pin1,	B.1	S.3	Vertical deflector RFQ up voltage AI
		G.3	Vertical deflector RFQ up voltage GND
TTL NI9403, slot8, pin2,	B.2	S.7	Vertical deflector RFQ down voltage AI
		G.7	Vertical deflector RFQ down voltage GND
TTL NI9403, slot8, pin3,	B.3	S.11	Horizontal deflector RFQ left voltage AI
		G.11	Horizontal deflector RFQ left voltage GND
TTL NI9403, slot8, pin4,	B.4	S.15	Horizontal deflector RFQ right voltage AI
		G.15	Horizontal deflector RFQ right voltage GND
TTL NI9403, slot8, pin5,	B.5	S.19	Vertical deflector ion 1 up voltage AI
		G.19	Vertical deflector ion 1 up voltage GND
TTL NI9403, slot8, pin6,	B.6	S.23	Vertical deflector ion 1 down voltage AI
		G.23	Vertical deflector ion 1 down voltage GND
TTL NI9403, slot8, pin7,	B.7	S.27	Horizontal deflector ion 1 left voltage AI
		G.27	Horizontal deflector ion 1 left voltage GND
TTL NI9403, slot8, pin8,	B.8	S.31	Horizontal deflector ion 1 right voltage AI
		G.31	Horizontal deflector ion 1 right voltage GND
TTL NI9403, slot8, pin11,	B.9	S.35	Vertical deflector ion 2 up voltage AI
		G.35	Vertical deflector ion 2 up voltage GND
TTL NI9403, slot8, pin12,	B.10	S.39	Vertical deflector ion 2 down voltage AI
		G.39	Vertical deflector ion 2 down voltage GND
TTL NI9403, slot8, pin13,	B.11	S.43	Horizontal deflector ion 2 left voltage AI
		G.43	Horizontal deflector ion 2 left voltage GND
TTL NI9403, slot8, pin14,	B.12	S.47	Horizontal deflector ion 2 right voltage AI
		G.47	Horizontal deflector ion 2 right voltage GND
TTL NI9403, slot8, pin15,	B.13	S.51	Vertical deflector ion 3 up voltage AI
		G.51	Vertical deflector ion 3 up voltage GND
TTL NI9403, slot8, pin16,	B.14	S.55	Vertical deflector ion 3 down voltage AI
		G.55	Vertical deflector ion 3 down voltage GND
TTL NI9403, slot8, pin17,	B.15	S.59	Horizontal deflector ion 3 left voltage AI
		G.59	Horizontal deflector ion 3 left voltage GND
TTL NI9403, slot8, pin18,	B.16	S.63	Horizontal deflector ion 3 right voltage AI
		G.63	Horizontal deflector ion 3 right voltage GND
TTL NI9403, slot8, pin20,	B.17		
TTL NI9403, slot8, pin21,	B.18		
TTL NI9403, slot8, pin22,	B.19		


TTL NI9403, slot8, pin23,
B.20
TTL NI9403, slot8, pin24,
B.21
TTL NI9403, slot8, pin25,
B.22
TTL NI9403, slot8, pin26,
B.23
TTL NI9403, slot8, pin27,
B.24
TTL NI9403, slot8, pin30,
B.25
TTL NI9403, slot8, pin31,
B.26
TTL NI9403, slot8, pin32,
B.27
TTL NI9403, slot8, pin33,
B.28
TTL NI9403, slot8, pin34,
B.29
TTL NI9403, slot8, pin35,
B.30
TTL NI9403, slot8, pin36,
B.31
TTL NI9403, slot8, pin37,
B.32
TTL NI9403, slot8, pin9, COM
B.33
TTL NI9403, slot8, pin10, COM
B.34

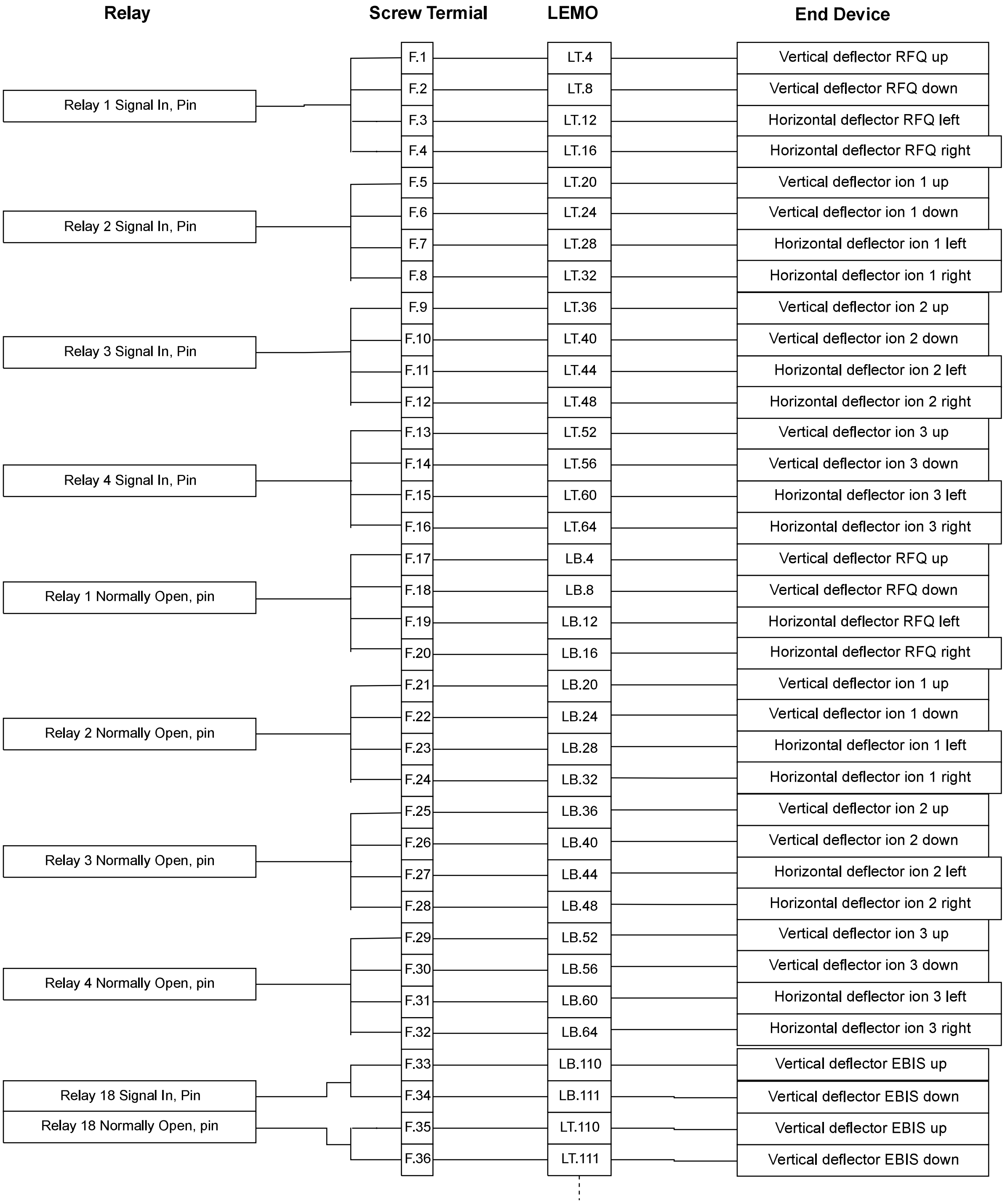
Connection diagram for the Front panel Perspective

Information

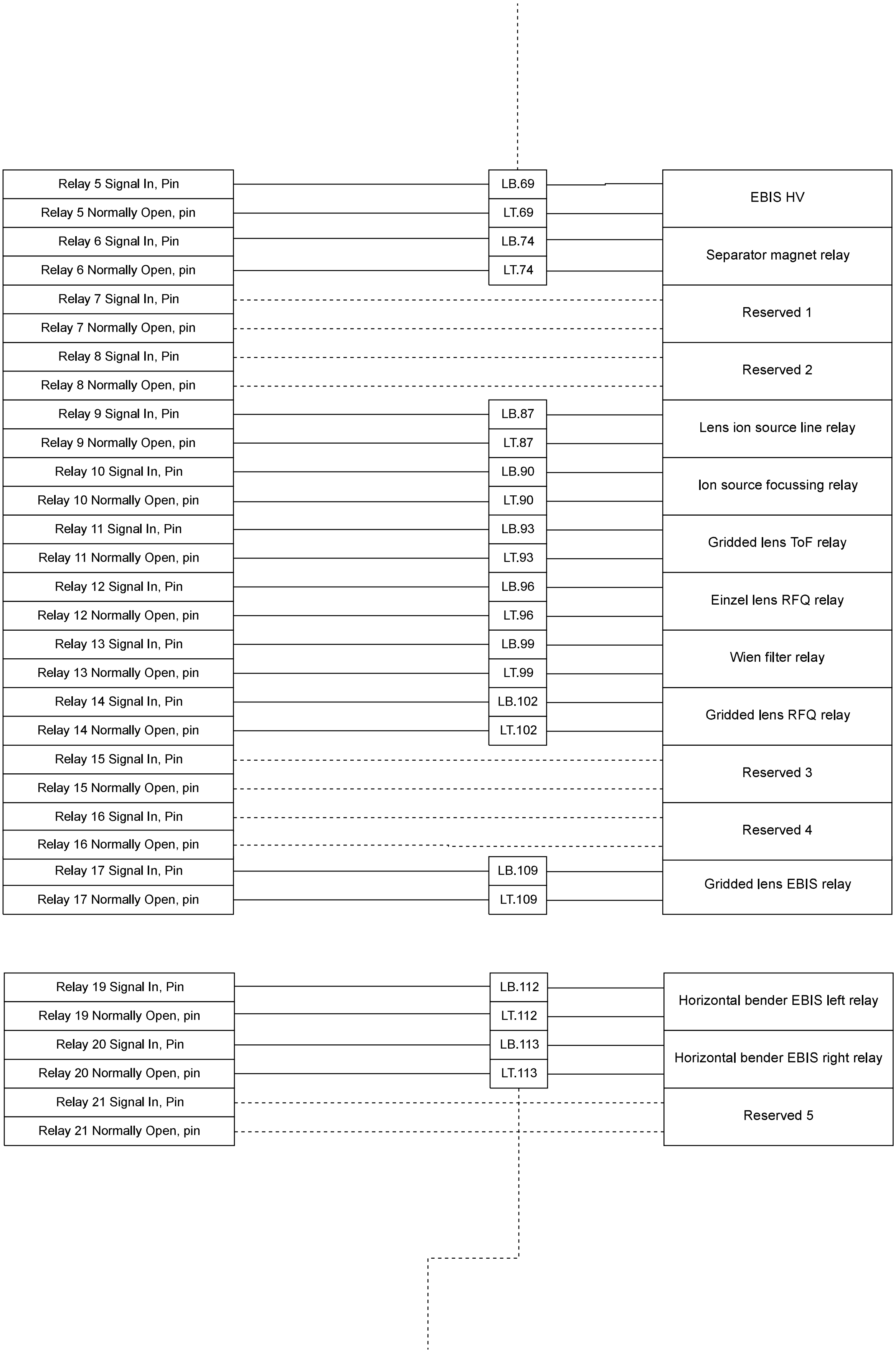
Platform: Ext. line PSU ground
Order: Screw terminal is in the correct order.

Definitions

F.x = Front Screw Terminal
LT.x = Top connector from LEMO connector x
LB.x = Bottom connector from LEMO connector x



Relay	Screw Termial	LEMO	End Device
Relay 1 Signal In, Pin	F.1	LT.4	Vertical deflector RFQ up
	F.2	LT.8	Vertical deflector RFQ down
	F.3	LT.12	Horizontal deflector RFQ left
	F.4	LT.16	Horizontal deflector RFQ right
Relay 2 Signal In, Pin	F.5	LT.20	Vertical deflector ion 1 up
	F.6	LT.24	Vertical deflector ion 1 down
	F.7	LT.28	Horizontal deflector ion 1 left
	F.8	LT.32	Horizontal deflector ion 1 right
Relay 3 Signal In, Pin	F.9	LT.36	Vertical deflector ion 2 up
	F.10	LT.40	Vertical deflector ion 2 down
	F.11	LT.44	Horizontal deflector ion 2 left
	F.12	LT.48	Horizontal deflector ion 2 right
Relay 4 Signal In, Pin	F.13	LT.52	Vertical deflector ion 3 up
	F.14	LT.56	Vertical deflector ion 3 down
	F.15	LT.60	Horizontal deflector ion 3 left
	F.16	LT.64	Horizontal deflector ion 3 right
Relay 1 Normally Open, pin	F.17	LB.4	Vertical deflector RFQ up
	F.18	LB.8	Vertical deflector RFQ down
	F.19	LB.12	Horizontal deflector RFQ left
	F.20	LB.16	Horizontal deflector RFQ right
Relay 2 Normally Open, pin	F.21	LB.20	Vertical deflector ion 1 up
	F.22	LB.24	Vertical deflector ion 1 down
	F.23	LB.28	Horizontal deflector ion 1 left
	F.24	LB.32	Horizontal deflector ion 1 right
Relay 3 Normally Open, pin	F.25	LB.36	Vertical deflector ion 2 up
	F.26	LB.40	Vertical deflector ion 2 down
	F.27	LB.44	Horizontal deflector ion 2 left
	F.28	LB.48	Horizontal deflector ion 2 right
Relay 4 Normally Open, pin	F.29	LB.52	Vertical deflector ion 3 up
	F.30	LB.56	Vertical deflector ion 3 down
	F.31	LB.60	Horizontal deflector ion 3 left
	F.32	LB.64	Horizontal deflector ion 3 right
Relay 18 Signal In, Pin	F.33	LB.110	Vertical deflector EBIS up
	F.34	LB.111	Vertical deflector EBIS down
Relay 18 Normally Open, pin	F.35	LT.110	Vertical deflector EBIS up
	F.36	LT.111	Vertical deflector EBIS down

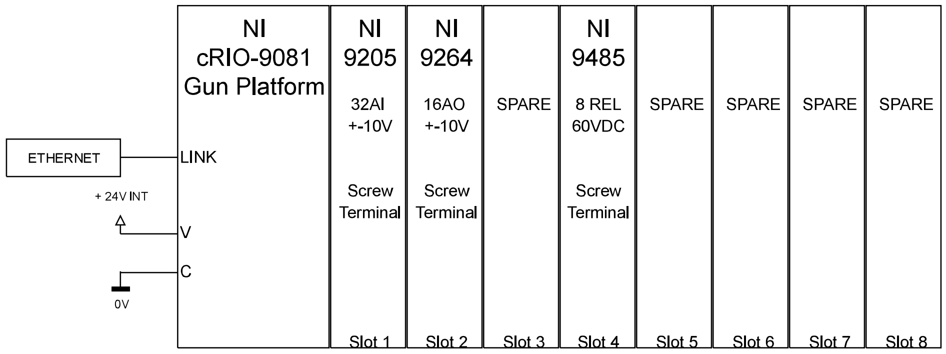


Relay 5 Signal In, Pin	LB.69	EBIS HV
Relay 5 Normally Open, pin	LT.69	
Relay 6 Signal In, Pin	LB.74	Separator magnet relay
Relay 6 Normally Open, pin	LT.74	
Relay 7 Signal In, Pin		Reserved 1
Relay 7 Normally Open, pin		
Relay 8 Signal In, Pin		Reserved 2
Relay 8 Normally Open, pin		
Relay 9 Signal In, Pin	LB.87	Lens ion source line relay
Relay 9 Normally Open, pin	LT.87	
Relay 10 Signal In, Pin	LB.90	Ion source focussing relay
Relay 10 Normally Open, pin	LT.90	
Relay 11 Signal In, Pin	LB.93	Gridded lens ToF relay
Relay 11 Normally Open, pin	LT.93	
Relay 12 Signal In, Pin	LB.96	Einzel lens RFQ relay
Relay 12 Normally Open, pin	LT.96	
Relay 13 Signal In, Pin	LB.99	Wien filter relay
Relay 13 Normally Open, pin	LT.99	
Relay 14 Signal In, Pin	LB.102	Gridded lens RFQ relay
Relay 14 Normally Open, pin	LT.102	
Relay 15 Signal In, Pin		Reserved 3
Relay 15 Normally Open, pin		
Relay 16 Signal In, Pin		Reserved 4
Relay 16 Normally Open, pin		
Relay 17 Signal In, Pin	LB.109	Gridded lens EBIS relay
Relay 17 Normally Open, pin	LT.109	

Relay 19 Signal In, Pin	LB.112	Horizontal bender EBIS left relay
Relay 19 Normally Open, pin	LT.112	
Relay 20 Signal In, Pin	LB.113	Horizontal bender EBIS right relay
Relay 20 Normally Open, pin	LT.113	
Relay 21 Signal In, Pin		Reserved 5
Relay 21 Normally Open, pin		

	Relay 1, 24V Input, Pin	Deflector RFQ relay
DO NI9477, slot5, pin1,	Relay 1, Ground, Pin	
	Relay 2, 24V Input, Pin	Deflector ion 1 relay
DO NI9477, slot5, pin2,	Relay 2, Ground, Pin	
	Relay 3, 24V Input, Pin	Deflector ion 2 relay
DO NI9477, slot5, pin3,	Relay 3, Ground, Pin	
	Relay 4, 24V Input, Pin	Deflector ion 3 relay
DO NI9477, slot5, pin4,	Relay 4, Ground, Pin	
	Relay 5, 24V Input, Pin	EBIS HV
DO NI9477, slot5, pin5,	Relay 5, Ground, Pin	
	Relay 6, 24V Input, Pin	Separator magnet relay
DO NI9477, slot5, pin6,	Relay 6, Ground, Pin	
	Relay 7, 24V Input, Pin	Reserved 1
DO NI9477, slot5, pin7,	Relay 7, Ground, Pin	
	Relay 8, 24V Input, Pin	Reserved 2
DO NI9477, slot5, pin8,	Relay 8, Ground, Pin	
	Relay 9, 24V Input, Pin	Lens ion source line relay
DO NI9477, slot5, pin11,	Relay 9, Ground, Pin	
	Relay 10, 24V Input, Pin	Ion source focussing relay
DO NI9477, slot5, pin12,	Relay 10, Ground, Pin	
	Relay 11, 24V Input, Pin	Gridded lens ToF relay
DO NI9477, slot5, pin13,	Relay 11, Ground, Pin	
	Relay 12, 24V Input, Pin	Einzel lens RFQ relay
DO NI9477, slot5, pin14,	Relay 12, Ground, Pin	
	Relay 13, 24V Input, Pin	Wien filter relay
DO NI9477, slot5, pin15,	Relay 13, Ground, Pin	
	Relay 14, 24V Input, Pin	Gridded lens RFQ relay
DO NI9477, slot5, pin16,	Relay 14, Ground, Pin	
	Relay 15, 24V Input, Pin	Reserved 3
DO NI9477, slot5, pin17,	Relay 15, Ground, Pin	
	Relay 16, 24V Input, Pin	Reserved 4
DO NI9477, slot5, pin18,	Relay 16, Ground, Pin	
	Relay 17, 24V Input, Pin	Gridded lens EBIS relay
DO NI9477, slot6, pin20,	Relay 17, Ground, Pin	
	Relay 18, 24V Input, Pin	Vertical deflector EBIS
DO NI9477, slot6, pin21,	Relay 18, Ground, Pin	
	Relay 19, 24V Input, Pin	Horizontal bender EBIS left relay
DO NI9477, slot6, pin22,	Relay 19, Ground, Pin	
	Relay 20, 24V Input, Pin	Horizontal bender EBIS right relay
DO NI9477, slot6, pin23,	Relay 20, Ground, Pin	
	Relay 21, 24V Input, Pin	Reserved 5
DO NI9477, slot6, pin24,	Relay 21, Ground, Pin	

cRIO Module setup and connection



TwinEBIS

cRIO Gun-Platform

ECHELLE
SCALE

SH-CERN	NOM/NAME	DATE
APPRO.		
CONTROL		
DES/DRA.	*Steen*	2019-05-03

REMPLACE/REPLACES

IND.

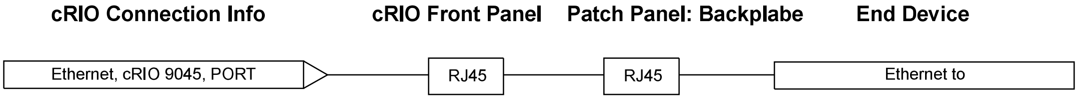
Connection Diagram from the cRIO Front Panel

Information

cRIO: Gun-Platform
Perspective: cRIO Front panel

Definitions

D-Sub X = D-sub connector



Connection Diagram for the Analog Input Module

Information

cRIO: Gun-platform
Perspective: Analog Inputs are in ascending order

Definitions

cRIO Connection Info	Patch Panel: Top	End Device
AI NI9205, slot1, pin1,	2	Cathode Heating
AI NI9205, slot1, pin2,	4	Cathode Heating
AI NI9205, slot1, pin3,	7	Wehnelt
AI NI9205, slot1, pin4,	9	Wehnelt
AI NI9205, slot1, pin5,	12	Anode Voltage
AI NI9205, slot1, pin6,	14	Anode Current
AI NI9205, slot1, pin7,	17	Suppressor Voltage
AI NI9205, slot1, pin8,	19	Suppressor Current
AI NI9205, slot1, pin19,	22	Collector
AI NI9205, slot1, pin20,	24	Collector
AI NI9205, slot1, pin21	27	Extractor Voltage
AI NI9205, slot1, pin22,	29	Extractor Current
AI NI9205, slot1, pin23,	32	Reserved Voltage
AI NI9205, slot1, pin24,	34	Reserved Current
AI NI9205, slot1, pin25,	37	Reserved Voltage
AI NI9205, slot1, pin26,	39	Reserved Current
AI NI9205, slot1, pin9,	NC	
AI NI9205, slot1, pin10,	NC	
AI NI9205, slot1, pin11,	NC	
AI NI9205, slot1, pin12,	NC	
AI NI9205, slot1, pin13,	NC	
AI NI9205, slot1, pin14,	NC	
AI NI9205, slot1, pin15,	NC	
AI NI9205, slot1, pin16,	NC	
AI NI9205, slot1, pin27,	NC	
AI NI9205, slot1, pin28,	NC	
AI NI9205, slot1, pin29,	NC	
AI NI9205, slot1, pin30,	NC	
AI NI9205, slot1, pin31,	NC	
AI NI9205, slot1, pin32,	NC	
AI NI9205, slot1, pin33,	NC	
AI NI9205, slot1, pin34,	NC	
AI NI9205, slot1, pin17,	NC	
AI NI9205, slot1, pin18,	NC	
AI NI9205, slot1, pin35,	X	Analog In Ground
AI NI9205, slot1, pin36,	NC	

Connection Diagram for the Analog Output Module

Information

cRIO: Gun-platform
Perspective: Analog Outputs are in ascending order

Definitions

cRIO Connection Info	Patch Panel: Top	End Device
AO NI9264, slot2, pin1,	1	Cathode heating
AO NI9264, slot2, pin2,	3	Cathode heating
AO NI9264, slot2, pin3,	6	Wehnelt
AO NI9264, slot2, pin4,	8	Wehnelt
AO NI9264, slot2, pin5,	11	Anode Voltage
AO NI9264, slot2, pin6,	13	Anode Current
AO NI9264, slot2, pin7,	16	Suppressor Voltage
AO NI9264, slot2, pin8,	18	Suppressor Current
AO NI9264, slot2, pin9,	21	Collector
AO NI9264, slot2, pin10,	23	Collector
AO NI9264, slot2, pin11,	26	Extractor Voltage
AO NI9264, slot2, pin12,	28	Extractor Current
AO NI9264, slot2, pin13,	31	Reserved Voltage
AO NI9264, slot2, pin14,	33	Reserved Current
AO NI9264, slot2, pin15,	36	Reserved Voltage
AO NI9264, slot2, pin16,	38	Reserved Current
AO NI9264, slot2, pin17,	X	Analog Out Ground
AO NI9264, slot2, pin18,	NC	
AO NI9264, slot2, pin19,	NC	
AO NI9264, slot2, pin20,	NC	
AO NI9264, slot2, pin21,	NC	
AO NI9264, slot2, pin22,	NC	
AO NI9264, slot2, pin23,	NC	
AO NI9264, slot2, pin24,	NC	
AO NI9264, slot2, pin25,	NC	
AO NI9264, slot2, pin26,	NC	
AO NI9264, slot2, pin27,	NC	
AO NI9264, slot2, pin28,	NC	
AO NI9264, slot2, pin29,	NC	
AO NI9264, slot2, pin30,	NC	
AO NI9264, slot2, pin31,	NC	
AO NI9264, slot2, pin32,	NC	
AO NI9264, slot2, pin33,	NC	
AO NI9264, slot2, pin34,	NC	
AO NI9264, slot2, pin35,	NC	
AO NI9264, slot2, pin36,	NC	

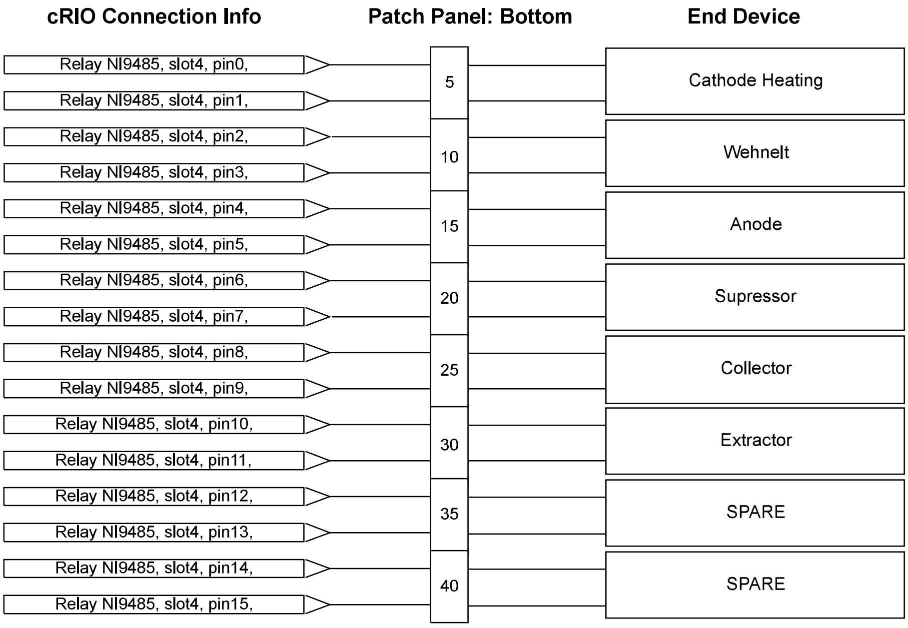
Connection Diagram for the Relay Module

Information

cRIO: HV-Platform
Perspective: Relays are in ascending order

Definitions

B.x = Bottom Screw Terminal



cRIO Connection Info	Patch Panel: Bottom	End Device
Relay NI9485, slot4, pin0, Relay NI9485, slot4, pin1,	5	Cathode Heating
Relay NI9485, slot4, pin2, Relay NI9485, slot4, pin3,	10	Wehnelt
Relay NI9485, slot4, pin4, Relay NI9485, slot4, pin5,	15	Anode
Relay NI9485, slot4, pin6, Relay NI9485, slot4, pin7,	20	Supressor
Relay NI9485, slot4, pin8, Relay NI9485, slot4, pin9,	25	Collector
Relay NI9485, slot4, pin10, Relay NI9485, slot4, pin11,	30	Extractor
Relay NI9485, slot4, pin12, Relay NI9485, slot4, pin13,	35	SPARE
Relay NI9485, slot4, pin14, Relay NI9485, slot4, pin15,	40	SPARE

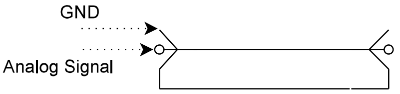
Connection Diagram for the backplane of the box

Information

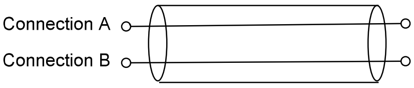
cRIO: Vacuum&Water, and Beam diagnostic
Perspective: Back panel Connectors are in ascending order

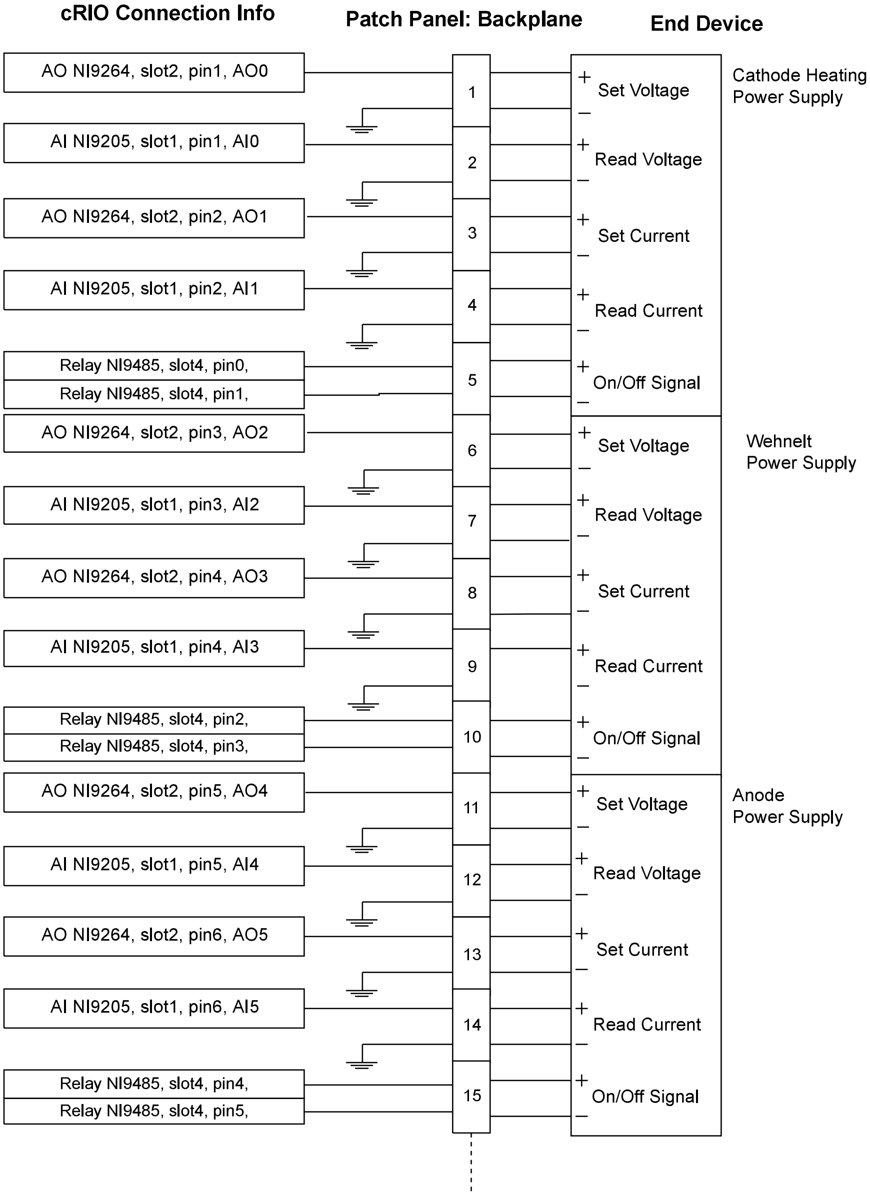
Definitions

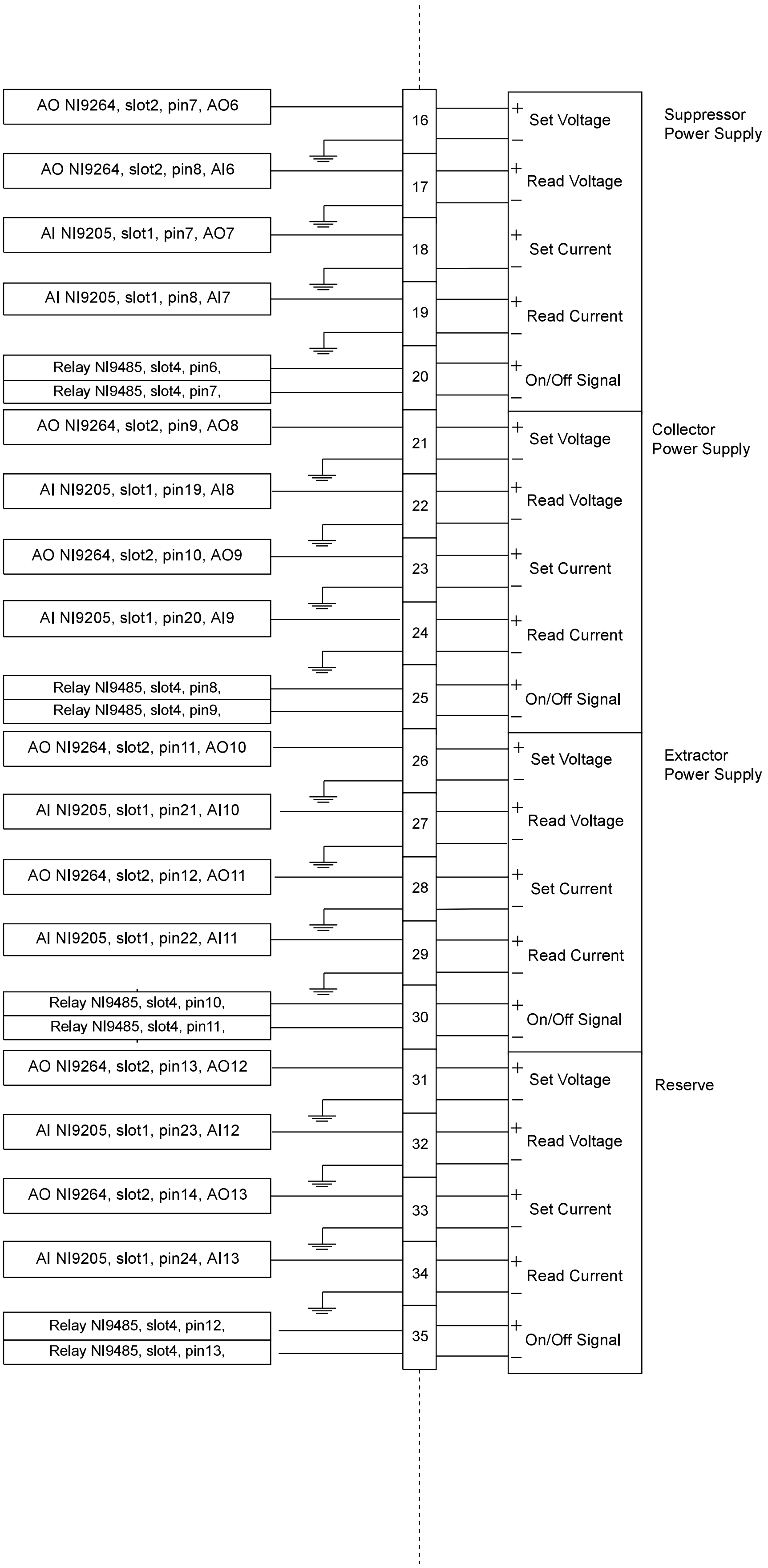
Most LEMOs are 00 and are connect and wired like this.

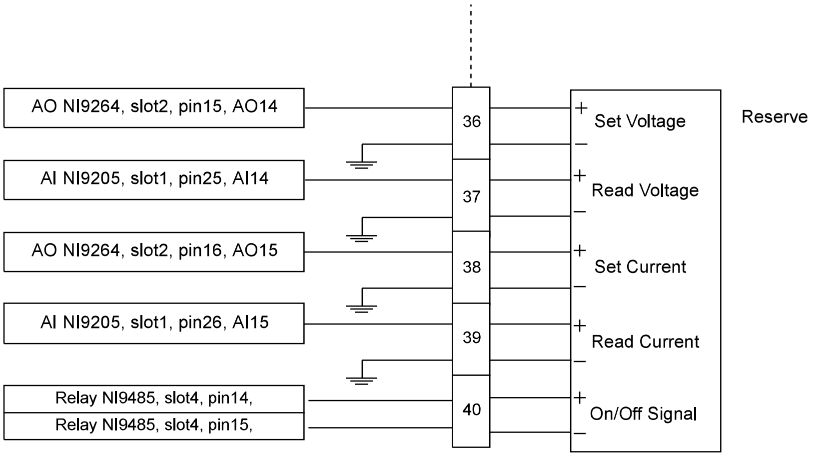


The relay uses LEMO 2 and has this type of connection and wiring






AO NI9264, slot2, pin7, AO6
AO NI9264, slot2, pin8, AI6
AI NI9205, slot1, pin7, AO7
AI NI9205, slot1, pin8, AI7
Relay NI9485, slot4, pin6,
Relay NI9485, slot4, pin7,
AO NI9264, slot2, pin9, AO8
AI NI9205, slot1, pin19, AI8
AO NI9264, slot2, pin10, AO9
AI NI9205, slot1, pin20, AI9
Relay NI9485, slot4, pin8,
Relay NI9485, slot4, pin9,
AO NI9264, slot2, pin11, AO10
AI NI9205, slot1, pin21, AI10
AO NI9264, slot2, pin12, AO11
AI NI9205, slot1, pin22, AI11
Relay NI9485, slot4, pin10,
Relay NI9485, slot4, pin11,
AO NI9264, slot2, pin13, AO12
AI NI9205, slot1, pin23, AI12
AO NI9264, slot2, pin14, AO13
AI NI9205, slot1, pin24, AI13
Relay NI9485, slot4, pin12,
Relay NI9485, slot4, pin13,
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
+ Set Voltage –
+ Read Voltage –
+ Set Current –
+ Read Current –
+ On/Off Signal –
Suppressor Power Supply
+ Set Voltage –
+ Read Voltage –
+ Set Current –
+ Read Current –
+ On/Off Signal –
Collector Power Supply
+ Set Voltage –
+ Read Voltage –
+ Set Current –
+ Read Current –
+ On/Off Signal –
Extractor Power Supply
+ Set Voltage –
+ Read Voltage –
+ Set Current –
+ Read Current –
+ On/Off Signal –
Reserve


AO NI9264, slot2, pin15, AO14
AI NI9205, slot1, pin25, AI14
AO NI9264, slot2, pin16, AO15
AI NI9205, slot1, pin26, AI15
Relay NI9485, slot4, pin14,
Relay NI9485, slot4, pin15,
36
37
38
39
40
+
Set Voltage
−
+
Read Voltage
−
+
Set Current
−
+
Read Current
−
+
On/Off Signal
−
Reserve