E158 Cryogenic Target Control System

Version 1.0

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Chapter 1

Introduction

1.1 Overview

The E158 target control system is shown in Figure 1.1. The desktop PC has two interface cards: a PCI-GPIB card and a PCI-MXI-2 card. The PCI-GPIB card talks to the GPIB devices: the Lakeshore 218S temperature monitor and the HP34401A multimeter. The Lakeshore temperature monitor measures the target loop and coolant temperature, while the HP34401A multimeter reads the tachometer for the target pump. The PCI-MXI-2 card is linked to the VXI-MXI-2 controller located inside the VXI-1200 FlexFrame crate by a MXI-2 cable. This VXI-1200 crate hosts a VXI-MIO-64E-1 module and a VXI-DIO-128 module. The MIO module has 64 analog input channels and reads the signals from the pressure transducers, beam current monitor, heater power supply, thermocouple gauge, cold cathode gauge, target position indicators, and pump motor controller. Its two analog output channels are used to control the heater current and voltage via the heater control box, and two of the eight digital output channels send TTL signals to the interlock box to disable the beam when the target parameters are outside the correct operating ranges or the computer/crate does not function properly. The DIO module has 64 digital input lines and 64 digital output lines. Its digital input channels are dedicated to monitoring the status of the manually operated valves on the target gas panel (2 TTL signals per valve). A laptop computer can monitor/control the target remotely via an ethernet connection using the TCP/IP connection. The system runs a program written in LabVIEW.

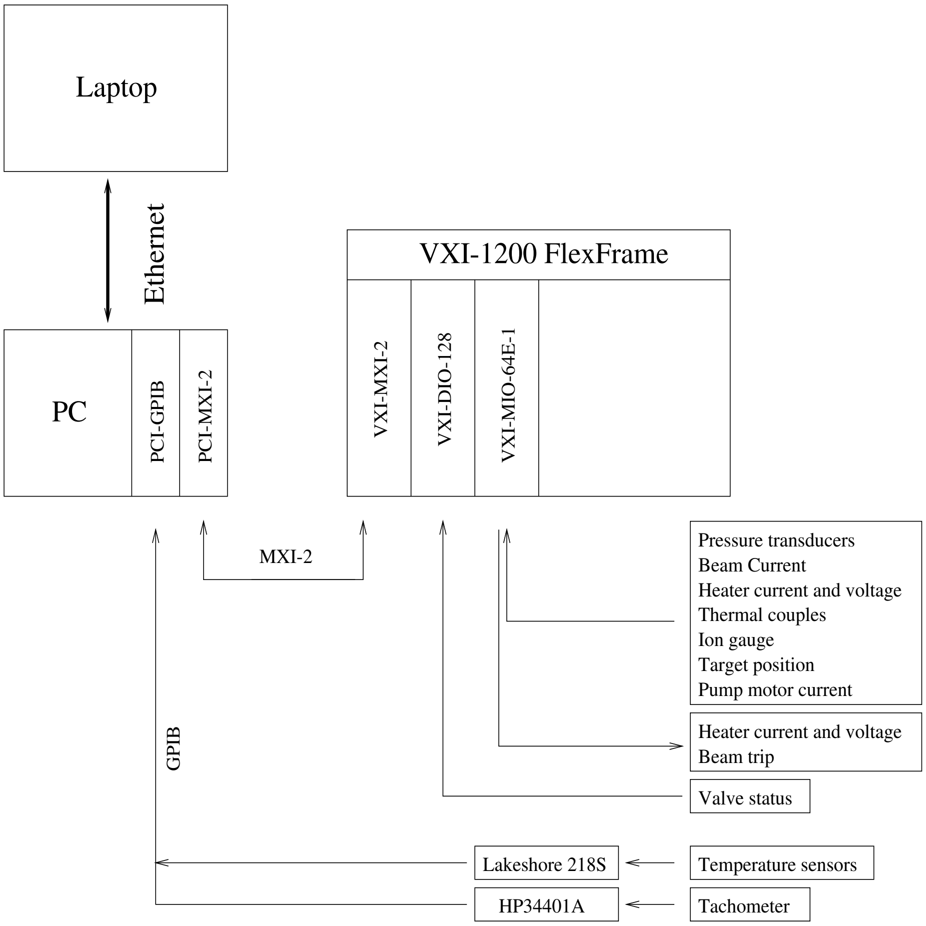

Figure 1.1: Schematic Display of E158 Target Control System

1.2 Hardware

The desktop computer and crate for the E158 target control will be located in ESA counting house. A summary of the signals read is given in Table 1.1. For the MIO and DIO modules, the analog input/output choice is the 0-10 V standard, while the digital input/output signals are TTL.

1.2.1 Temperature measurement

The E158 target uses four Cernox sensors to measure the temperature in the cryoloop and two additional Cernox sensors to monitor the coolant inlet and outlet temperature. The four-lead, Lakeshore CX-1070-AA-4L sensors are located at the two ends of the loop pump and the heater, as well as the coolant inlet and outlet. They are calibrated from 4 to 325 Kelvin. The calibration curves are entered into a Lakeshore 218S temperature monitor to which the sensors are connected.

1.2.2 Beam current

The electron beam going through the target is measured by a beam current monitor (BCM) located on the beamline upstream of the target. The BCM is calibrated. The generated 0-10 V analog signal is sent to an analog input channel of the MIO module and converted to beam current reading.

1.2.3 Pressure transducers

The E158 target gas handling system uses the Omega PX880 and PX771 pressure transducers located on the gas panel to measure the gas pressure. The output 4-20 mA current signals are transformed to 2-10 V voltage signals, sent to the analog input channels, and converted into pressure readings.

1.2.4 Tachometer

The loop pump speed is monitored with a tachometer. The tachometer consists of a magnetic ring and a pick up coil. The magnetic ring is mounted on the pump shaft, while the pick up coil standing nearby generates AC signal which has the same frequency as the pump speed. The AC signal is sent to a HP34401A multimeter to read out the frequency.

1.2.5 Target loop heater

The target heater uses a Sorenson DCS33-33E power supply, which has the maximum output power of 1 kW (33 V & 33 A). The output current and voltage are remotely controlled with two 0-10 V signals set by the analog output channels of the MIO module.

When the computer/crate hangs up or is unavailable, a control box should be manually switched on to control the target heater power supply. This control box has the analog signals from the MIO module, and itself generates two manually adjustable 0-10 V analog signals as well. Two 0-10 V analog outputs are connected to the heater power supply. A switch selects whether the analog output signals come from the MIO module or the control box. An LED display indicates computer control of the heater power supply. Once the computer is working again, the target operator must set the

DAC for the power supply so that the heater power is the same as before. Therefore, there is no sudden heat load changes when the computer takes the control over.

1.2.6 Vacuum measurement

The vacuum of the scattering chamber is monitored by a Leybold Combivac CM 31 vacuum gauge which has a thermocouple TR211 sensor and a cold cathode Penningvac PR35 sensor. The analog outputs (0-10 V) from these two sensors are sent to the analog input channels of the MIO module and converted to vacuum pressure readings.

1.2.7 Target position

Both the horizontal and the vertical target positions are monitored. The analog signals corresponding to the target position are read by the MIO analog input channels.

1.2.8 Valve status

The status of the valves on the target gas panel is monitored by the digital input channels of the DIO module. With two independent TTL signals generated from the two microswitches on each valve, one can determine four possible valve states: open, closed, half-way, and power failure.

1.2.9 Beam interlocks

When the target parameters are out of the set ranges and the software interlock trips, a TTL signal generated by the digital output channel of the MIO module will disable the beam via the beam interlock box. A computer heartbeat signal generated by a separate digital output channel of the MIO module is also sent to the beam interlock box. If the computer or crate fails, the beam will trip.

Model	Device	Device I/O	Module	Quantity
Omega	pressure	4-20 mA/0-100,300,3000 psi	MIO/AI	6
SLAC	beam current	0-20 μA/0-10 V	MIO/AI	1
Sorenson	heater current	0-10 V/0-33 A	MIO/AO	1
Sorenson	heater voltage	0-10 V/0-33 V	MIO/AO	1
Leybold	cold cathode	10^{-9}-10^{-2} mbar/0-10 V	MIO/AI	1
Leybold	thermocouple	10^{-4}-10^{3} mbar/0-10 V	MIO/AI	1
SLAC	target position	0-50 cm/0-10 V	MIO/AI	2
Caltech	beam interlocks	TTL	MIO/DO	2
Caltech	valve status	TTL	MIO/DI	18
Balder	motor current	0-5 V/0-4 A	MIO/AI	1
Lakeshore	temperature	10 μA/4-325 K	GPIB	4
HP34401A	tachometer	0-3600 RPM	GPIB	1

Table 1.1: Summary of Target Control Electronics

1.3 Software

LabVIEW 5.1 from the National Instruments is used as the graphical interface for the target monitor and control system. The LabVIEW program consists of a series of Virtual Instruments (VI's) which are similar to the subroutines in other programming languages. Each VI has a front panel which displays results and provides interaction with the user, and a diagram which decides the flow of the program using wires, loops, and sequences. The control program has the following listed features.

- It provides graph charts showing the parameters related to the target operating (temperature, pressure, beam current etc.) as a function of time and target status information. It also displays the target phase diagram.
- It provides an interactive interface with the user. The user can change the running conditions and save them to a text file.
- It allows the user to access the subsystems, such as the status of the valves, the target heater, the gas panel etc.
- It can record the data and replay the data. The user can select the length of the data file, the number of sampling per data point.
- It can send the data to cryogenic and DAQ groups via ethernet. Signals listed in Table 1.2 are sent to BridgeVIEW running at the cryogenic group.

Signal	Description	Quantity
Temperature (K)	Heater exchanger inlet	1
	Heater exchanger outlet	1
	Pump inlet	1
	Pump outlet	1
Pressure (psi)	H2 supply	1
	ΔP across pump	1
	Vent out line	1
Pump motor(RPM)	Speed	1
Heater (W)	Heater power	1

Table 1.2: Summary of Signals Sent to BridgeVIEW via Ethernet

- It can provide an animated image on the website while it is running.
- It can be run on a laptop computer to remotely control/monitor the system.
- It can be run in the simulation mode so that the user can test different running conditions.

Chapter 2

Running the Control Program

2.1 Start the Program at the Desktop Computer

The steps to start the target control program at the desktop computer are the following:

1. Log on the target control computer. The username is *target*, and the password is *control*. They are case sensitive.

2. Double click on the shortcut to the file *chtt.vi* which is located in the directory /home/target/E158. Under the menu bar of *chtt.vi*, there are a row of buttons. Click on the RUN button (the first one from the left, shaped like an arrow), the arrow should turn from an outline to black, indicating that the VI is running.

3. A file dialog will prompt, asking the user to select a parameter file. The default is *chtt.par* which is in the same directory of the main VI.

4. The control initialization window appears. The user may change several parameters before the program starts taking data.

   Sample Interval This is the time of each reading cycle. The unit is second. The suggested value will be 2 seconds.

   Device Simulation Click this on will set the program running in simulation mode.

   Settings Click on this will save the parameters into a file.

   Logging Click on this will prompt a data logging page, allowing the user to enable/disable the data logging and change the related parameters.

   Alarms Click on this will prompt a page to access the alarms and interlocks.

If the simulation ON is selected, the simulation page will appear, allowing the user to change the parameters simulating the apparatus. Click OK will exit from this page.

5. Click OK on the control initialization window. The data taking will start.

2.2 Starting the Program from the Laptop Computer

In the process of liquefying hydrogen, one needs to monitor the target status from the End Station A. A laptop computer is dedicated for this purpose. The laptop computer communicates with the desktop computer via ethernet. When the desktop launches the Remote Device Access (RDA) server, the VXI devices (the MIO and DIO modules) are *visible* to the laptop computer. The laptop treats them as its own devices. However, the GPIB devices (Lakeshore 218S and HPO34401A) can not be accessed remotely. The data from the GPIB devices will be transmitted by the LabVIEW TCP/IP data server. Here are the steps to launch the target control program from the laptop.

1. Close the target control program *chtt.vi* at the desktop computer to avoid confusion.

2. Start the Remote Device Access server (**START/PROGRAM/NI-DAQ/RDA**) at the desktop computer.

3. Start running *DataServer.vi* by clicking on its shortcut at the desktop computer.

4. Start the Remote Device Access server (**START/PROGRAM/NI-DAQ/RDA**) at the laptop computer.

5. Start running target control program *chtt.vi* at the laptop following the steps described in the previous section.

2.3 Stop the Program

Click the **STOP** button in the lower left corner of the front panel, a dialog box will appear and ask the user to confirm ending the running. Click on the OK button, the program will stop after the current cycle is finished, and the RUN button in the upper left corner of the front panel will turn to outline from black solid.

An alternative to stop the program is clicking on the STOP sign right below the LabVIEW menu bar. This will stop the program immediately regardless what is happening. However, **one should awlays use the STOP button.**

Chapter 3

Displays

3.1 Main Control Panel

The main panel of the target control program displays seven graph charts showing the time evolution of target pressures, heat loads, target temperatures, coolant temperatures, vacuum pressures, and gas bottle pressures. At the upper right corner of the main panel, there is a target temperature-pressure phase diagram plot, with four curves respectively indicating target frozen, boiling, 1K and 2K subcooled. Below the gas bottle pressure diagram, there is a region showing the status of target monitoring and hardware interlocks. Below the charts, there is a message window displaying the messages related to the target monitoring. The background color of the message window can be green, yellow or red, indicating normal condition, alarm warning and interlock tripping information. At the bottom of the main panel, there are a row of controlling buttons. A detailed description of these buttons is the following:

Pause stops the charts from scrolling. After the charts stop scrolling, a scroll bar appears, allowing the charts to be scrolled back in time.

Chart Width selects the width of the charts in minutes. The maximum chart width is about 60 minutes.

Clear Charts clears all the strip charts.

STOP stops the target control program. A dialog box will prompt to confirm the intention.

Valves display the status of the valves.

Alarms allows the user to enable/diable the alarms and beam inetrlocks.

Graph	Parameter	Description
Target Pressure (PSIG)	Loop	Pressure from PT13
	P3	Pressure from PT3
	Ballast	Ballast tank pressure
Differential Pressure (PSID)	Pump	Pressure from PT20
Heater Load (W)	Ibeam	Beam current (μA)
	Pbeam	Heat load from beam
	Phtr	Heater power
	Ptot	Total heat on loop
Loop Temperature (K)	Tpo	Temperature after pump
	Tpi	Temperature before pump
	Tho	Temperature after heater
	Thi	Temperature before heater
Coolant Temperature (K)	Tci	Coolant inlet temperature
	Tco	Coolant outlet temperature
Vacuum (mTorr)	TC	Thermocouple
	CC	Cold cathode
H2 Supply (PSI)	H2	H2 bottle pressure

Table 3.1: Summary of the Parameters in the Graph Charts

Heater controls the target loop heater.

Logging allows the user to turn on/off the data logging and change the logging parameters.

Settings allows the user to save the parameters into a file.

Target displays the targets on the ladder and highlights the one being used.

Gas Panel shows a schematic layout of the gas panel. The status of each valve, pressures, and temperatures of the system are also displayed.

Simulation allows the user to change the parameters used in the simulation.

A summary of the descriptions of the parameters displayed in the graph charts is listed in Table 3.1.

3.2 Changing Graph Axes

3.2.1 Vertical Axes

LabVIEW has two modes for setting the graph axes, AUTOSCALE ON/OFF. To change from one mode to another, the user can put the cursor on the graph, hold down the right mouse button. A pop menu will appear, and user can select AUTOSCALE X (or Y) ON/OFF. If the autoscaling is off, and the user wants to change the axis limits, then simply highlight the upper or lower limit, and edit them one by one. To save the changes made, just click on the SAVE option under the FILE menu.

3.2.2 Horizontal Axes

The horizontal axies of all the graph charts have been synchronized. The units of the axes are time and the width of all the charts are adjusted by the **chart width** which sets the width of the charts in minutes. To scroll the charts back in time:

1. Click on the **Pause** button. A scroll bar will appear.
2. Scroll the charts back to the desired point.
3. After finishing checking the charts in the past, move the scroll bar back to the right most (most recent).
4. Click on the **Pause** button to resume normal chart updates.

3.3 Secondary Control Panels

3.3.1 Heater

The heater control panel is used to adjust the power settings for the target heater, and set the maximum combined heat load on the target loop from the beam current and the heater. The heater has four possible modes:

- **BYPASS**: The heater is not controlled by the computer.
- **OFF**: The heater power is set at 0.
- **AUTO**: The computer calculates the power needed to keep a total heat load on the target loop at a fixed, user-selected value (the **Auto Power Setting**).
- **MANUAL**: The heater power supply puts out a constant power (the **Manual Power Setting**) set by the user.

When the LabVIEW program starts, the heater control mode is always set at **BYPASS**. The target operator needs to make sure the heat load from the heater is the same when the other control modes are switched to. When the LabVIEW program is stopped by clicking on the **STOP** button, a dialog will ask if it is intended to leave the heater on.

Manual Power Setting is the heater power set by the user when the target heater is in manual mode. The maximum allowed setting is 1000 W or **Maximum Target Power** which ever is smaller. The power can only be set in 10 W increments.

Auto Power Setting is for automatic adjustment of the heater (AUTO mode) to compensate for the power deposition of the beam. The heater power is set by $P_{heater} = P_{auto} - P_{beam}$.

Maximum Target Power is the maximum combined heat load allowed on the target.

Heater Voltage Set is the voltage to be set on the heater.

Heater Current Set is the current to be set on the heater.

Voltage DAC Set is the DAC value necessary to set the heater voltage. 0-10 VDC reference voltage set by the DAC corresponds to 0-33 VDC output voltage on the heater power supply.

Current DAC Set the DAC value necessary to set the heater current. 0-10 VDC reference voltage set by the DAC corresponds to 0-33 A output current on the heater power supply.

Beam Power shows the beam power deposited on the target.

Heater Set Power Output shows the heater power level set by the control program.

Heater Output Power shows the heater output power as measured from the voltage and current of the heater power supply.

Maximum Target Temperature is the maximum target loop temperature below which the target heater can be turned on. Whenever the target loop temperature reaches that point, the heater is turned off automatically. The default setting is 100 K, and it can be changed.

3.3.2 Logging

The logging control panel controls recording the target data to disk. It first averages the variables over a number of data samples and then writes the averaged values to the disk. The number of writes (the data file length) is adjustable.

Data Logging enables/disables the data logging.

Samples Averaged is the number of samples averaged over before writing to disk.

Record Per File is the number of records written to the data file.

log path is the path of the file to which the data logging information is written.

data path is the path of the data file.

number of samples is the current number of samples read.

dat is the data from the current read.

sum is the sum of the samples averaged over.

ave is the average of the samples.

3.3.3 Gas Panel

This page shows a schematic layout of the target and gas panel. The status of the valves and readouts of the temperature and pressures are displayed. The valves can have four states: open (green), half open (green and fuzzy), closed (red), and failed (red and fuzzy).

3.3.4 Valves

This page display the status of each valve.

3.3.5 Settings

The settings control panel can save the current parameters to a file (*chtt.par*) by clicking on the SAVE button.

3.3.6 Target

This panel displays which target is being used, target is moving or not, and the target position encoder. The user can also select one of the four temperature readings: pump in, pump out, heater in, or heater out, as the temperature for the phase diagram.

3.3.7 Alarms

There are two types of warning indicators: alarm and software beam interlock. Alarms indicate something that needs attention. When there is an alarm, a message is generated, a warning bell rings, and the background of the message window turns yellow. The alarms available are: beam current more than 12 μA, heat deposited by the target heater too high, target pump circulating speed out of the range, coolant inlet/outlet temperatures out of the ranges, or the target is not in the right position. Software beam interlocks are events that can trip the beam. When there is a beam interlock, the message window becomes red and a message is generated as well. Software beam interlocks include: the valves on the gas panel do not satisfy the truth table corresponding to normal operating condition, or the loop temperature is out of the range.

Alarms and beam interlocks can be disabled/enabled and the trip points for all the parameters can be adjusted. When the program starts, the settings for the alarms and beam interlocks are read from the parameter file *chtt.par*, and can be saved to this file with the SETTINGS SAVE function. **One has to be extremely careful about changing the settings of the alarms and interlocks. Only target expert can make the decision!**

3.3.8 Simulation

This panel allows the user to input the parameters and the noises used for the simulation.

Chapter 4

Target Operation

4.1 Saving or Loading Parameters from File

Most of the control system parameters than can be changed by the user can be saved to or loaded from a file. When the control system is first started, it prompts the user for a parameter file (the default is *chtt.vi* in the same directory as the *chtt.vi*). To save the current parameters to a file,

1. click on the **Settings** button on the main panel,

2. click on **Save**. A dialog box will pop up asking for the file to save the parameters to. The default is *chtt.par*.

4.2 Alarms and Interlocks

The alarms and interlocks are enabled/disabled and set via the **Alarms** control panel which is opened by clicking the **Alarms** button on the main panel. The alarms panel includes two parts: **Alarms** and **Interlocks**. The settings related to alarms and interlocks are saved when the control system parameters are saved.

4.2.1 Alarms

When one of the alarms trips, the bell rings once, and the background of the message window turns yellow. Each alarm has an enable/disable button, and three numeric displays: **low set point, current value**, and **high set point**. The message window may be still yellow after the situation is corrected. To reset the window to green (no alarm, normal situation), click on the **reset Alarms** button.

4.2.2 Interlocks

If one of the interlocks trips, a warning is given. If there are three warnings in a row, the interlock trips the beam off, and the message window becomes red. After the interlock is recovered, one can click on the **reset Alarms** button to make the message window green.

The valve interlock triggers the interlock and alarm if the states of the valves do not match a mask. There are two masks available:

Hydrogen valve states for liquid hydrogen running,

Helium valve states for gaseous helium running.

To select the desired mask:

1. select the **Set Valve Interlocks** button on the **Alarm** panel,
2. select the desired valve mask by selecting either **Hydrogen** or **Helium**,
3. close the valve interlock panel by clicking **OK**.

Individual valves can be put into or taken out of the interlock by clicking on the **enable/disable** button next to each valve name. The desired state for the valve in the interlock is selected by clicking on the **open/close** button next to each valve name. The settings are saved when the parameters are saved to the file.

4.3 Target Heater

The target loop heater consists of two independent 2.0 Ω coils. In normal running, these two coils are connected in parallel. The connection is made outside of the scattering chamber. This way, if one coil fails, the other coil can still be used. The target heater is powered by a Sorenson 33V 33A DC power supply capable of supplying up to 1 kW power. The power supply is normally operated as a Current Controlled Voltage Source (CCVS) meaning that a reference voltage (from an anolog output channel of the MIO module) is supplied to the power supply which selects the output voltage. The current of the supply is determined by the fixed voltage and the resistance of the load. However, the maximum allowed current of the power supply can also be specified by a separate reference voltage (from another analog output channel of the MIO module). By fixing the maximum allowed current, the maximum power output from the power supply is also fixed.

The manner in which the power supply is operated is configured by jumpers on the 25 pin D connector on the back of the power supply. The power supply can not be operated simutaneously from its front and from the voltage reference. The reference voltage can be either from the analog output channels of the MIO module or the heater manual control box.

4.3.1 Computer Heater Control

The heater is normaly controlled by the computer. There are two modes of operation available, **Manual** and **Automatic**. The other two modes are **OFF** which turns the heater off or **BYPASS** where the computer does not control the heater power supply. When switching between modes, it is always necessary to make sure that the new mode will put the same amount of heat on the target as the old mode. **Do not make large sudden changes in target heater power**.

When the heater control is in manual mode, the heat load stays at the value set by the computer until the mode is changed or the heat load requested is changed. The steps to set the heater in manual mode are the following:

1. Click the **Heater** button on the main control to open the heater control panel.
2. Ensure that the **Maximum Target Power** is equal to or greater than the desired heat load.
3. Set the desired manual heat load using the **Manual Power Setting** control.
4. Switch the heater mode to **MANUAL**.

In Automatic mode, the computer is given a total heat load on the target. It calculates the heat load from the beam, then adjusts the heater power so that the total heat load on the target stays at the set point. This calculation and adjustment is done every read cycle. The Automatic mode is the normal operating mode when the beam is on the target. To set the automatic heat load:

1. Click the **Heater** button on the main control to open the heater control panel.
2. Ensure that the **Maximum Target Power** is equal to or greater than the desired heat load.
3. Set the desired manual heat load using the **Auto Power Setting** control.
4. Switch the heater mode to **AUTO**.

4.3.2 Manual Heater Control from the Counting House

If the computer/crate fails, the heater needs to be controlled from the heater manual control box. By switching to the manual heater control, the user can override the computer of the target heater and control the power supply from the manual control box. The DACs for the heater voltage and current limit need to be set at the total target loop heat load before the computer/crate fails, so that there is no heat load change to the loop after the manual control switch is turned on. The computer always does not know if the control has been overridden or not.

Chapter 5

If Things Go Wrong

5.1 Computer or Crate Crashes

If the computer or crate crashes, the electron beam will be shut down right away automatically by the interlock system. The first thing for the target operator is then to switch the target heater control to **manual** on the heater manual/remote control box so that the same heat load is maintained on the target loop. To recover the system:

1. Turn off the VXI crate, unplug the VXI crate power cord, and unplug the BNC cables from the MIO breakout box for the following signals: pressure transducers, software interlock, and computer heartbeat.

2. Wait for 10 seconds, then plug the VXI crate power cord in, and turn on the VXI crate.

3. Turn on the computer. If the computer is already on, run **Start/Program/National Instruments VXI/Resman**. If **Resman** can not be finished without error messages, repeat step 1-3. If **Resman** still can not be normally finished, contact the target expert.

4. Plug the BNC cables in one by one and very slowly. Wait for about 5 seconds before plug the next cable in.

5. Start running the LabVIEW program. If the pressure transducer reading is bizarre, repeat step 4.

Everytime the VXI crate is power cycled, the user needs to follow the steps 1-5. If the **Resman** hangs, the user should contact the target expert immediately.

The pressure transducers and the software interlock, computer heartbeat use the +24 V/+5 V power supply from the DIO-128 module. These power supplies have some protection circuits and can reset themselves to 0 V when the current reaches the limit. Therefore, before the VXI crate is turned on or power cycled, one needs to unplug the BNC cables from the MIO box for the pressure transducers and the interlocks. After the VXI crate is turned on, the user needs to put the BNC cables back one by one to avoid resetting the power supply.

5.2 Frequent Warning Messages

The user should pay attention to any warning messages and beeps. If the warning is frequently triggered by the false readings, the user may consult with the target expert and then change the limits for that warning to reasonable values. One must be very careful about changing the warning/interlock settings. Only the target expert can make such kind of decisions.

5.3 GPIB Devices

Sometimes during the running, the GPIB devices (mostly the HP34401A multimeter) may lose communication with the computer. The symptom is that the LabVIEW gives a warning, saying that the HP34401A is not found. Also on the front panel of the HP34401A, the reading is not updated. The user needs to power cycle the HP34401A, and then press the button 'freq' on the front panel of the HP34401A. Once the HP34401A reads the tachometer correctly, the target operator can stop the LabVIEW program and restart it.

Chapter 6

Program Description

6.1 System Configuration

After the crate and the computer are turned on, the system configuring program **T & M Explorer** runs automatically. The computer will recognize the VXI and GPIB devices. A list of the logical/GPIB addresses of the devices is shown in Table 6.1

Device Name	address	VXI Device No.
PCI-MXI-2	Logical Address 0	NA
VXI-MXI-2	Logical Address 1	NA
VXI-DIO-128	Logical Address 4	1
VXI-MIO-64E-1	Logical Address 3	2
Lakeshore 218S	GPIB Address 12	NA
HP34401A	GPIB Address 22	NA

Table 6.1: List of Logical/GPIB addresses of the VXI/GPIB device

6.2 Software Description

The target control program was written in LabVIEW (version 5.1). The main VI (Virtual Instrument) has a front panel which displays the graph charts as well as some messages, and a diagram which is basically the source program. The diagram has several blocks: initialization, reading the device, updating the charts, setting the heater, checking the alarm, displaying the message, accessing the subsystem, and networking. Each block can have some sub-VIs. One can access the sub-VI by double-clicking on the corresponding icon. All the blocks and sub-VIs are connected by the local and global variables. The local variables can be read/written in a single VI, while the global variables are shared by all the VIs. The program is executed like this: after the program is initialized, the computer starts reading the device, at the same time, it updates the charts, checks the alarms, displays the messages, checks if there is a request to access the subsystems, sets the heater to appropriate value, and sends the data to the network. The sub-VIs are sorted into the following libraries:

IO.llb contains the VIs directly communicating with the VXI and GPIB devices.

ctrlchtt.llb contains the VIs related to the controlling.

chttpar.llb contains the VIs related to the parameter reading/writing.

graphchtt.llb contains the VIs for generating graphs.

globalchtt.llb contains the VIs for global variables.

misc.llb contains some miscellaneous VIs such as generating messages and so on.

libchtt.llb contains some VIs which are not sorted.

TCPIPDataServe.llb contains the VIs related to networking.

6.2.1 Initialization

The initialization of the program uses a sequence structure. It has 12 frames. A description of the main function of each frame is listed in the following

Frame 0 define the directories of the data files and message files. The ending program global variable **Gendprog** is set at FALSE. The program version is also defined.

Frame 1 define valve names, set the interlock variables.

Frame 2 read the parameters. The default parameter file name is chtt.par .

Frame 3 check the device, including VXI modules and GPIB devices.

Frame 4 initialize some global variables.

Frame 5 initialize some global variables related to the interlocks.

Frame 6 initialize the data logging, including variable names, data format, and data file names.

Frame 7 initialize the charts. The default chart width is 20 minutes.

Frame 8 initialize the control. A dialog VI *control_initialize.vi* pops up, allowing the user to make necessary changes.

Frame 9 initialize some target control global variables. The heater mode is set at **BYPASS** mode. The message window is initialized.

Frame 10 define the hydrogen phase diagram.

Frame 11 initialize the data arrays, including the analog signals and temperature readings. The calibration constants of the analog signals are also defined here, $y = mx + b$, y is the physical quantity, x is the raw ADC signal, m and b are the calibration constants.

6.2.2 Read the Devices

Four while loops are used to read the four devices, MIO-64-E1 module, DIO-128 module, the Lakeshore temperature monitor, and the HP-34401A multimeter separately. The reading cycle is controlled by the global variable **Greadtime**, and the default value is 2 seconds. When the simulation is turned on (**Gsimulate** is set at TRUE), inside each reading device while loop, the program will look for the simulated data instead of the real device readings. For the GPIB devices (Lakeshore temperature monitor and the HP-34401A multimeter) as well as the DIO-128 module , the raw data is also the final physical quantities. While for the MIO-64-E1 module, the raw data are converted to the physical quantites using the calibration constants.

6.2.3 Update the Charts

Three while loops are used to update the charts. One while loop keeps looking for the boolean **Pause**. Once the **Pause** is clicked, a scroll bar will appear and the user can roll the charts back. By default, the **Pause** is set at FAULT, and the data is displayed on the charts. Another while loop synchronizes the charts, making them having the same chart width and being updated at the same frequency. It also looks for the boolean **Clear** to reset all the charts. The main while loop does the following: it computes the timing information (time period for every read cycle, time stamp), combines the data into an array format so that it can be logged on the disk, updates the phase diagram, and organizes the data so that they can be read by the charts.

6.2.4 Set the Heater

The setting of the appropriate heater power is accomplished by a while loop. First, the program will look for the current heater mode. If the heater mode is not **BYPASS**, the program will access the VI *heater_set.vi* . Inside that VI, the program first looks for the heater mode and the wanted power, then computes the necessary heater voltage and current, converts them to the values for the DAC, and sets the DAC channels to the corresponding values. For the heater power supply, 0-10 V DAC corresponds to 0-33 V or 0-33 A.

6.2.5 Check the Alarms

A while loop is dedicated for this purpose. Whenever the program is reading the data (**Genable_read** is set at TRUE), the VI *alarm_check.vi* is accessed. This VI contains a sequence of two frames. The first frame checks the alarms, and the second frame checks the software interlocks. In the checking alarm frame, the program first checks if the alarm is enabled. If it is, then there is a sequence with the same number of frames as the alarms. Each frame corresponds to each alarm. Inside each frame, the program compares the value with the its upper/lower limits. If the value is out of the range, a warning message will be generated. The checking interlock frame has a similar structure. It not only checks each interlock, but also looks for three identical warnings in a row. If this happens, interlock trips. Also, when there is a warning, the message window background is set to be yellow, and when there is an interlock trip, the message window is set to be red.

6.2.6 Display the Message

Inside the message loop, the program keeps looking for the message flag **Gmesflag**. That flag is turned on only if the VI *message_put.vi* is accessed, i.e. the program needs to generate some message. Then the messages are displayed through the VI *message_disp.vi* , which can display the messages in the message window. The message window changes color accordingly: green means normal, yellow means warning, and red means interlock trip. The VI *beep.vi* also runs if there is a warning or interlock trip. The user can also hear a short beep if there is a warning, and three consecutive beeps if there is an interlock trip.

6.2.7 Access the Subsystem

The while loop for accessing the subsystem contains a sequence of nine frames, corresponding to the nine boolean buttons located at the lower left corner of the front panel. If one of the button is clicked, the program will execute the corresponding VI.

Frame 0 stops the program. Once the **STOP** is clicked, a confirming page will pop up. If the user clicks on **OK**, the program will then execute the VI *end_heater_check.vi*, asking if the user wants to leave the heater on. After that, the global variable **Genable** will be set at FALSE and the program stops.

Frame 1 displays the valve status. Once the **Valves** is clicked, the program will execute the VI *control_valves_n.vi* .

Frame 2 accesses the alarms and interlocks. Once the **Alarms** is clicked, the program executes the VI *control_alarm.vi* .

Frame 3 controls the heater. Once the **Heater** is clicked, the program executes the VI *control_heater.vi* .

Frame 4 controls the data logging. Once the **Logging** is clicked, the program executes the VI *control_logging.vi* .

Frame 5 controls the target parameter settings. Once the **Settings** is clicked, the program executes the VI *control_settings.vi* .

Frame 6 displays what kind of target is in use. Once the **Target** is clicked, the program executes the VI *tgt_disp.vi* .

Frame 7 displays the gas panel. Once the **Gas Panel** is clicked, the program executes the VI *gas_dis_nohe.vi* .

Frame 8 accesses the simulation. Once the **Simulation** is clicked, the program executes the VI *sim_ctl.vi* .

6.2.8 Network

There are two program blocks which do the data transfer through the network. The VI TCPIPDataServer.vi is always running in the background, waiting for network connection and sending data once there is a connection request, the other block just combines the data into an array.

Chapter 7

Wiring of the Target Control System

Figure 7.1 shows the schematic of the target control system wiring. In normal running, the following items will be located in the counting house of ESA: computer, crate, motor controller, Lakeshore temperature monitor, heater power supply and its manual/override box, analog/digital breakout box, and beam interlock box. While the breakout box for the temperature sensors, vacuum gauge, close-valve box and gas panel will be located right outside of the target shielding wall in ESA. The computer and the crate are connected by a MXI-2. Two identical SH96-96 shielded cables from National Instruments connect the DIO/MIO modules and the TBX-96 connectors inside the digital/analog breakout boxes. A GPIB cable connects the Lakeshore temperature monitor as well as the HP34401A multimeter to the GPIB port on the computer.

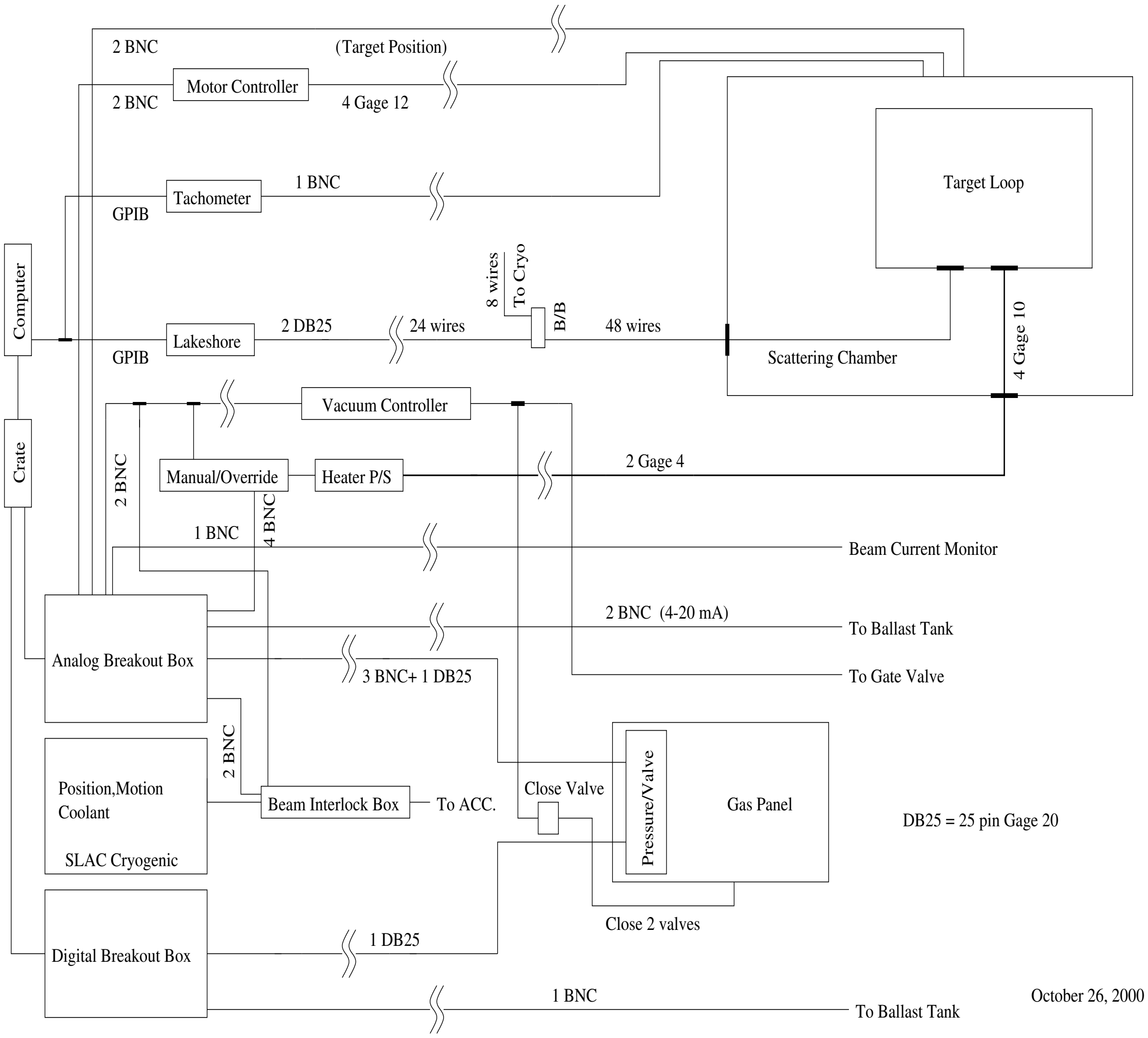

Figure 7.1: Schematic Display of E158 Target Control Wiring

7.1 Analog Breakout Box

The analog breakout boxes has 24 isolated BNC connectors and 2 DB 25 connectors. At this moment, the DB 25 connectors are not used. The BNC connectors are numbered in this way: the top-left one is No. 1, then the number increases by one from left to right for the first row, and the second row starts with No. 7. The BNC cables monitor/control the following siganls: target positions, motor pump speed/current, scattering chamber vacuum, heater voltage/current, software inter-

TBX-96 Connector	Breakout Box	Description
A23 (ACH0)	BNC 1	Target Position Horizontal
B22 (ACH1)	BNC 2	Target Position Vertical
C21 (ACH2)	BNC 3	Motor Pump Current
A21 (ACH3)	BNC 4	Motor Pump Speed
A20 (ACH4)	BNC 5	Thermovac
B19 (ACH5)	BNC 6	Cold Cathode
C18 (ACH6)	BNC 7	Heater Voltage
A18 (ACH7)	BNC 8	Heater Current
C22 (ACH8)	BNC 9	Beam Current
C17(ACH15)	BNC 10	Spare ADC channel
A24 (DAC0OUT)	BNC 11	Heater Voltage DAC
C23 (DAC1OUT)	BNC 12	Heater Current DAC
A22 (ACH9)	BNC 13	Pressure Transducer 1 (Gas Panel)
B21 (ACH10)	BNC 14	Pressure Transducer 2 (Gas Panel)
C20 (ACH11)	BNC 15	Pressure Transducer 3 (Gas Panel)
C19 (ACH12)	BNC 16	Pressure Transducer 1 (Ballast)
A19 (ACH13)	BNC 17	Pressure Transducer 2 (Ballast)
B18 (ACH14)	BNC 18	Pressure Transducer 3 (Ballast)
C24 (DIO0)	BNC 19	Software Interlock
B25 (DIO1)	BNC 20	Computer Heartbeat

Table 7.1: Analog Breakout Box Wire Map

lock, computer heartbeat, and pressure transducers. Table 7.1 lists the wire map for the analog breakout box. Notice that inside the analog breakout box, there are two relays and a circuit. One relay converts the software digital interlock signal to a contact signal. The other relay and the circuit generate another contact signal from the computer heartbeat. For both relays, the logic is that if the contact is open, the beam is off, if the contact is closed, the beam can be on.

7.2 Digital Breakout Box

The digital module monitors the status of the vales. It also serves as the +5 V, +24 V power supply for the microswitches and the pressure transducers. The +5 V, +24 V power supply can be cut off by a relay which is controlled by the hydrogen sniffers. The digital breakout box has 2 DB 25 connectors and 16 isolated BNC connectors.

The first DB 25 connector (the left one) is used. While the BNCs and the other DB 25 are reserved for future use. Table 7.2 is the digital breakout box wire map.

7.3 Temperature Sensors

Twelve Cernox sensors are used to monitor the target temperature. At each of the four locations: before the pump, after the pump, before the heater, and after the heater, two sensors (a primary, a spare) are mounted. Only one sensor from each location is hooked up to the temperature monitor unit, while the leads of the rest four sensors are hanging inside the breakout box. In this way, if a sensor malfunctions, it can be easily replaced. The temperature of the coolant inlet and outlet is monitored by four sensors (two sensor at each location, one goes to the cryogenic group, the other is connected to the Lakeshore temperature monitor). Inside the scattering chamber, the 48 leads of the sensors wrapped with ceramic tubing are connected to a DB 50 pin connector on the scattering chamber. An individually shielded twisted-pair cable connects the leads to a breakout box. Inside the breakout box, the 48 leads split: 24 of them go to the target temperature unit, 8 of them go the cryogenic group, and 16 of them stay. The 24 leads going to the target temperature unit are split into two groups: 16 of them are connected to the first four channels of the temperature unit by one DB 25 connector, and the rest 8 leads are connected to the channel five and six of the temperature unit by another DB 25 connector. A wire map of the sensors is listed in Table 7.3 and 7.4.

7.4 Heater Power Supply

The Sorenson DCS33-33E power supply has a DB 25 connector at its back. To configure the power supply in the remote mode (the output voltage and current are controlled by two 0-10 VDC signals), three jumpers have to be made. These jumpers connect pin No. 3 and No. 16, pin No. 12 and No. 24, pin No. 13 and No. 25. The jumper for pins 12-24 and the pin No. 2 are connected to ground. Five BNC cables (labeled as 1, 2, 3, 4, and 5, summarized in Table 7.6) connected to five pins of the DB 25 connector provide monitoring/controlling signals for the power supply.

TBX-96 Connector	Pin No./DB No.	Description
B31	1/1	Ground for +5 V
B30	2/1	+5V
A30	3/1	MV4 open
C29	4/1	MV4 close
B29	5/1	MV12 open
A29	6/1	MV12 close
C28	7/1	PV12 open
B28	8/1	PV12 close
A28	9/1	MV13 open
C27	10/1	MV13 close
B27	11/1	SV13 open
A27	12/1	SV13 close
C26	13/1	MV20 open
B26	14/1	MV20 close
A26	15/1	MV21 open
C25	16/1	MV21 close
B25	17/1	PV21 open
A25	18/1	PV21 close
A22	19/1	MV30 open
C21	20/1	MV30 close
B21	21/1	Spare open
A21	22/1	Spare close
B22	23/1	+24 V
C20	BNC 1	Valve on ballast

Table 7.2: Digital Breakout Box Wire Map

Serail No./Location	Color	50 Pin No.	Pin No./DB No.
11089/TI501 A	White	2	3/1
11089/TI501 A	White	3	4/1
11089/TI501 A	Black	4	15/1
11089/TI501 A	Black	5	16/1
12178/TI501 B	White	6	N/A
12178/TI501 B	White	7	N/A
12178/TI501 B	Black	8	N/A
12178/TI501 B	Black	9	N/A
12155/TI500 A	White	10	6/1
12155/TI500 A	White	11	7/1
12155/TI500 A	Black	12	18/1
12155/TI500 A	Black	13	19/1
12189/TI500 B	White	14	N/A
12189/TI500 B	White	15	N/A
12189/TI500 B	Black	16	N/A
12189/TI500 B	Black	17	N/A
12157/TI503 A	White	18	9/1
12157/TI503 A	White	19	10/1
12157/TI503 A	Black	20	21/1
12157/TI503 A	Black	21	22/1
12190/TI503 B	White	22	N/A
12190/TI503 B	White	23	N/A
12190/TI503 B	Black	24	N/A
12190/TI503 B	Black	25	N/A
12174/TI502 A	White	26	12/1
12174/TI502 A	White	27	13/1
12174/TI502 A	Black	28	24/1
12174/TI502 A	Black	29	25/1
12200/TI502 B	White	30	N/A
12200/TI502 B	White	31	N/A
12200/TI502 B	Black	32	N/A
12200/TI502 B	Black	33	N/A

Table 7.3: Target Loop Temperature Sensor Wire Map

Serail No./Location	Color	50 Pin No.	Pin No./DB No.
10589/TI400 B	White	34	3/2
10589/TI400 B	White	35	4/2
10589/TI400 B	Black	36	15/2
10589/TI400 B	Black	37	16/2
10461/TI401 B	White	38	6/2
10461/TI401 B	White	39	7/2
10461/TI401 B	Black	40	18/2
10461/TI401 B	Black	41	19/2
TI400 A	White	42	3/3
TI400 A	White	43	4/3
TI400 A	Black	44	15/3
TI400 A	Black	45	16/3
TI401 A	White	46	6/3
TI401 A	White	47	7/3
TI401 A	Black	48	18/3
TI401 A	Black	49	19/3

Table 7.4: Coolant Temperature Sensor Wire Map

Location Code	Location
TI500 A	Pump In Primary
TI500 B	Pump In Spare
TI501 A	Pump Out Primary
TI501 B	Pump Out Spare
TI502 A	Heater In Primary
TI502 B	Heater In Spare
TI503 A	Heater Out Primary
TI503 B	Heater Out Spare
TI400 A	Coolant In Cryogenic Group
TI400 B	Coolant In Target Group
TI401 A	Coolant Out Cryogenic Group
TI401 B	Coolant Out Target Group

Table 7.5: Explanation of the Location Code

BNC No.	DB 25 Pin No.	Description
1	7	Output Current
2	9	Input Voltage (DAC)
3	10	Input Current (DAC)
4	19	Output Voltage
5	14	TTL Input (High=Power OFF)

Table 7.6: BNC Cables for the Heater Power Supply

Chapter 8

Data Replay

The data saved on disk can be replayed by running a different VI, *chtt_read.vi* . Here is the procedure to replay data:

1. Double click on the shortcut to the file *chtt_read.vi* to bring up the replay VI.

2. Click on the RUN button (the first one, arrow shaped button under the menu bar). A dialog window appears. By default, the program will look for the data file in the directory /home/target/E158/data. Click on the data file name to be replayed.

3. Besides the seven charts on the target control main panel, the tachometer (speed of the pump) is also displayed. Click on the button **Pause**, a scroll bar will appear so that one can move back and forth. Also, if one changes the horizontal axis limits of the first graph (the top left one), all the other charts will be changed accordingly. The start and end time of the data displayed is also indicated on the front panel.

4. Click on the **STOP** button to stop the program and restart it to load a different data file.