

Aachen University of Applied Sciences, Campus Jülich

Department: Energy Technology

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Bachelor Thesis

Control and operation of an Imageplate-Scanner for X-ray diffraction

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This bachelor thesis has been carried out at the Institute of Jülich Centre for Neutron Science (JCNS) of the Research Center Jülich (FZ-Jülich).

This thesis was supervised by:

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DI Peter Hiller

I certify that this work has been carried out and written up entirely by myself. No literature references and resources other than those cited have been used.

Jülich, Oct.2011 _____



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1. Introduction of the system

The project is to scan a maximum 500mm × 500mm area neutron image plate by every 1mm grid with a Laser beam that is reflected by a moving magnet motor controlled reflector system.

For each grid point there will be an analog value, that measured by photomultiplier tube and then it is saved into the memory.

It should be also possible to read out the data and display into an intensity graph. The system and the electronic components of the GSI-Lumonics Group must work with the Class-3B-Laser to set up an experiment.

The LabVIEW, which is used in the project, is from the National Instrument Company.

Practical work procedure:

- Learn LabVIEW to be familiar with using and building programs.
- Set-up the hardware system with the electronic components of the GSI-Lumonics Group and connect with the host computer with LabVIEW.
- Set-up another circuit to control laser, lamp and photomultiplier tube with DAQ-Card, terminal block and relay.
- Install the program CLI.exe (Command Line Interface) from the CD of GSI Group, and be familiar with using commands to control the system.
- Use LabVIEW to build up an own program to control the system also laser, lamp and photomultiplier tube with the SubVIs that are in the CD.
- Also write one part program that can acquire and proceed the data that will be displayed into an intensity graph.

THE ORIGINAL PROJECT DESCRIPTION:**Steuerung und Inbetriebnahme eines Imageplate-Scanners für Röntgendiffrakometrie**

Als 2-dimensionalen Detektor für eines unserer Röntgendiffraktometer möchten wir eine Röntgen-Imageplate mit einem Scanner benutzen, der programmierbar vor Ort die Imageplate ausliest und die Daten über ein Computersystem zur Verfügung stellt. Eine Röntgen-Imageplate ist heutzutage kommerziell erhältlich und wird in der medizinischen Röntgentechnik serienmäßig verwendet. Allerdings wird sie dort im allgemeinen nicht am Ort der Belichtung ausgelesen, sondern ausserhalb des Röntgenstrahls in einem externen Scanner. Wir hingegen möchten Sie am Ort der Belichtung auslesen können, um ohne Justageungenauigkeiten mehrfache Experimente durchführen zu können.

Wir haben einen Aufbau fertiggestellt (s.Abbildung), in dem mittels eines Lasers und zwei Spiegelgalvanometer die Platte systematisch gescannt werden kann. Die Fluoreszenzstrahlung der belichten Imageplate wird dann mit einem Photomultiplier detektiert und über einen AD-Wandler in den Computer eingelesen. Die aufbereiteten Messwerte sollen gespeichert und visualisiert werden.

Die Steuerungs- und Projektierungssoftware ist LabVIEW von National Instruments. Die Arbeit setzt auf ein bestehendes Softwaregerüst auf. Das Projekt umfasst den Aufbau, die Inbetriebnahme und abschließenden Test der Hard- und Software unter Messbedingungen.

Die Arbeit wird betreut von Herrn DI Klaus Bussmann (Elektrotechnik, Laborleiter des Elektroniklabors) und Herrn DI Peter Hiller (Physikalische Technik, Laborleiter des Röntgenlabors).

2. Scanning of neutron image plate

Neutron image plate (NIP) has found widespread application as neutron detectors for single-crystal and powder diffraction, small-angle scattering and tomography. After neutron exposure, the image plate can be read out by scanning with a laser (see figure 2.1). Commercially available NIPs consist of a powder mixture of BaFBr : Eu²⁺ and Gd₂O₃ dispersed in a polymer matrix and supported by a flexible polymer sheet. Since BaFBr : Eu²⁺ is an excellent x-ray storage phosphor, these NIPs are particularly sensitive to γ -radiation which is always present as a background radiation in neutron experiments. In this work we present results on NIPs consisting of KCl : Eu²⁺ and LiF that were fabricated into ceramic image plates in which the alkali halides act as a self-supporting matrix without the necessity for using a polymeric binder. An advantage of this type of NIP is the significantly reduced γ -sensitivity. However, the much lower neutron absorption cross section of LiF compared with Gd₂O₃ demands a thicker image plate for obtaining comparable neutron absorption. The greater thickness of the NIP inevitably leads to a loss in spatial resolution of the image plate. However, this reduction in resolution can be restricted by a novel image plate concept in which a ceramic structure with square cells (referred to as a ‘honeycomb’) is embedded in the NIP, resulting in a pixelated image plate. In such a NIP the read-out light is confined to the particular illuminated pixel, decoupling the spatial resolution from the optical properties of the image plate material and morphology. In this work, a comparison of experimentally determined and simulated spatial resolutions of pixelated and unstructured image plates for a fixed read-out laser intensity is presented, as well as simulations of the properties of these NIPs at higher laser powers.

-<Pixelated neutron image plates>

Certain materials, notably BaFBr:Eu²⁺, have energy levels below the conduction band which can be populated when x-rays de-excite in the material. These levels cannot de-excite to lower levels and are sufficiently below the conduction band that thermal excitation to the conduction band is very unlikely. Photoexcitation, e.g., by a red laser, into the conduction band then allow de-excitation with the emission of a blue photon. This is photostimulated luminescence. A phototube covered with a filter to only pass blue photons then can sense the magnitude of photostimulated luminescence without sensing scattered red laser photons. An intense flood of light is used to totally photostimulate the plate, thereby erasing it.

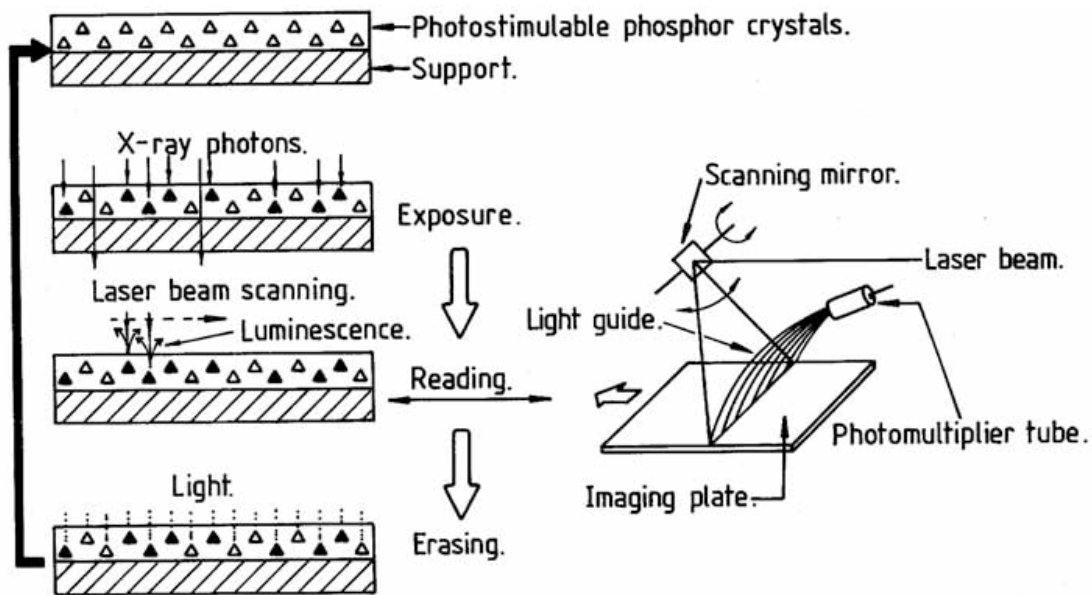


Figure 2.1 Principle of neutron image plate exposure and evaluation

Also known as an image plate, a photostimulable phosphor (PSP) plate can be used to record a two-dimensional image of the intensity of short-wavelength (typically, X-ray) electromagnetic radiation. The device to read such a plate is known as a phosphorimager (occasionally abbreviated to phosphoimager, perhaps reflecting its common application in molecular biology of detecting radiolabeled phosphorylated proteins and nucleic acids).

3. LabVIEW

3.1 Introduction of LabVIEW

What is NI LabVIEW ?

LabVIEW is a graphical programming environment used by millions of engineers and scientists to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. It offers unrivaled integration with thousands of hardware devices and provides hundreds of built-in libraries for advanced analysis and data visualization – all for creating virtual instrumentation. The LabVIEW platform is scalable across multiple targets and OSs, and, since its introduction in 1986, it has become an industry leader.

-<http://www.ni.com/labview/whatis/>

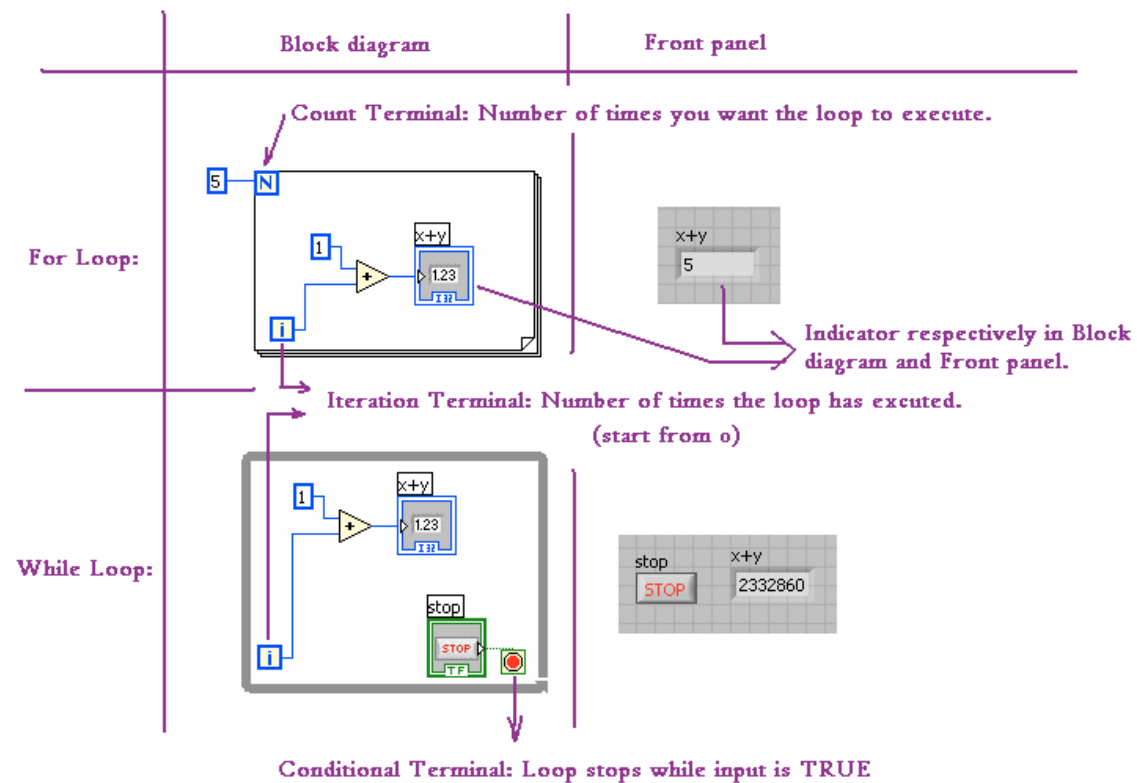
LabVIEW is a powerful and flexible development software and designed specifically for the needs of scientists and engineers. It uses the graphical programming language **G** to create programs which called **virtual instruments (VIs)** in the **block diagram**. The user interacts with the program through the **front panel**. LabVIEW has many build-in functions to facilitate the programming process.

Block diagram: Pictorial representation of a program or algorithm. In G language, the block diagram, which consists of executable icons, called nodes, and wires that carry data between the nodes, is the source code for the VI.

Front panel: The interactive interface of a VI. Modeled from the front panel of physical instruments, it is composed of switches, slides, meters, graphs, charts, gauges, LEDs, and other controls and indicators.

3.2 Basic use

Example1: for loop and while loop



For loop: Calculate 5 times, i starts from 0 not 1, so the last time $i=4$, the indicator display the result $i+1=5$.

While loop: Keep calculating till press the stop button, if the $i=2332859$ at that moment, the indicator display the result $i+1=2332860$.

For loop in other programming language:

Java

```
for (int i=0; i<10; i++){
    System.out.println("The value of 'i' is " + i );
}
```

C++

```
int i;

for (i=0; i<10; i++){

    cout << "The value of 'i' is " << i << endl;

}
```

While loop in other programming language:

Java

```
int i = 0;

while (i < 10){

    System.out.println("The value of 'i' is " + i);

    i++;

}
```

C++

```
int i = 0;

while (i < 10){

    cout << "The value of 'i' is " << i << endl;

    i++;

}him
```

Example2: case structure

In case structure, we use normally boolean, which has TRUE and FALSE value. When the boolean is true, the program runs the process only in true structure (Figure 3.1). When the boolean is false, the program runs the process only in false structure (Figure 3.2). It's easy to make a program with case structure and it's very useful.

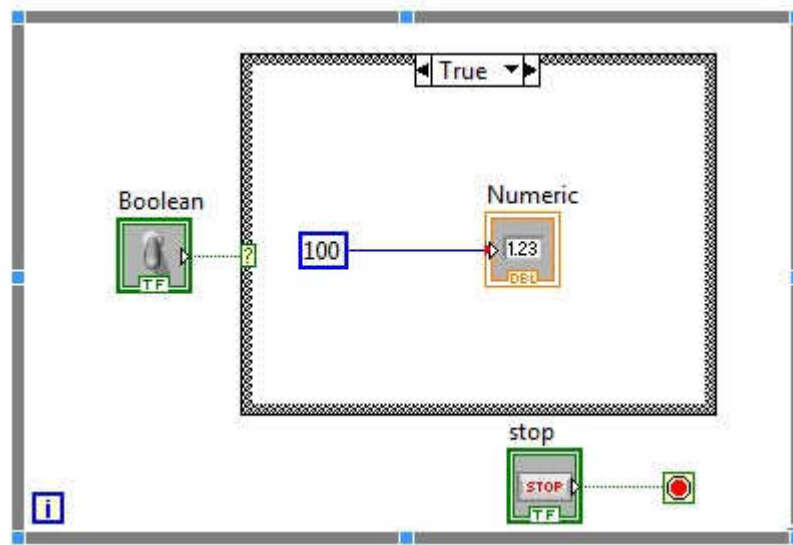


Figure 3.1 True case

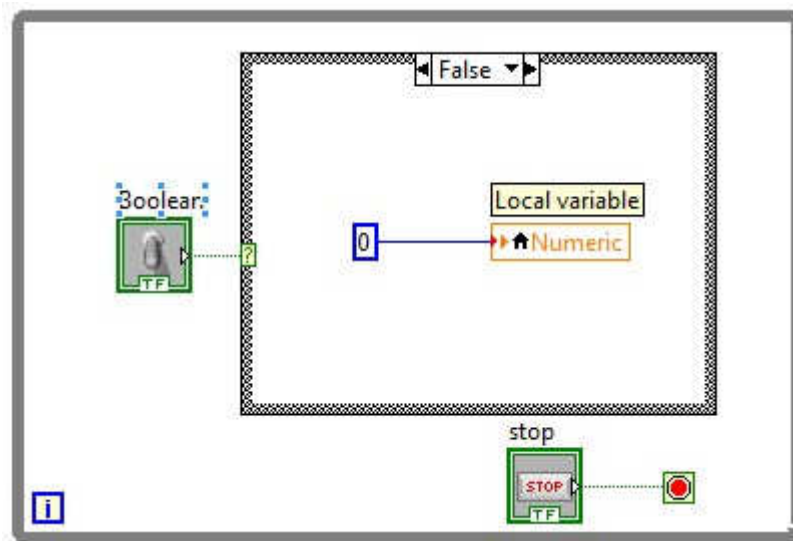


Figure 3.2 False case

Example3: data acquisition (DAQ)

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (abbreviated with the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing. The components of data acquisition systems include (see figure 3.3):

- Sensors that convert physical parameters to electrical signals.

- Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Data acquisition applications are controlled by software programs developed using various general purpose programming languages such as BASIC, C, Java, MATLAB and LabVIEW.

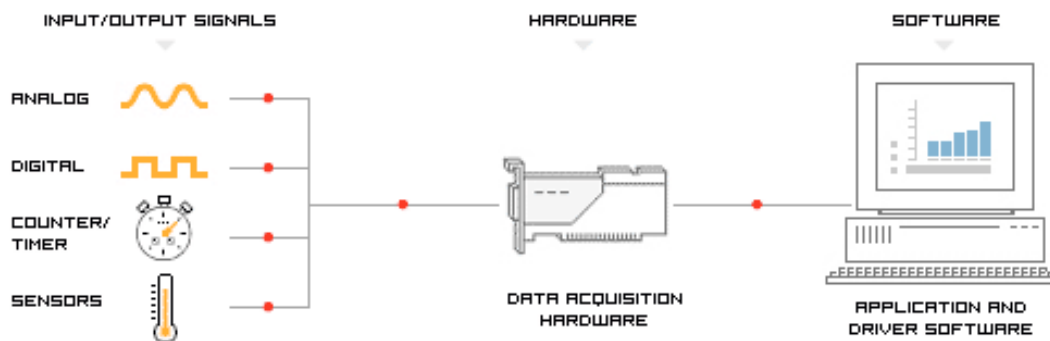


Figure 3.3 Data acquisition system

First of all, we must install DAQ-Driver, that can be downloaded from NI website. When we place the DAQ Assistant Express VI on the block diagram, the DAQ Assistant automatically appears. And then we can choose acquire or generate of analog or digital signals. The DAQ Assistant is a graphical interface that we can use to configure measurement tasks and channels. We use acquire analog signal to get voltage value.

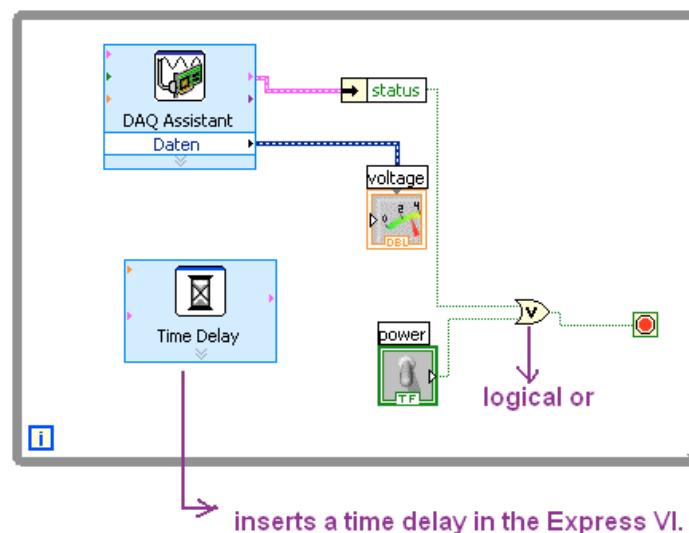


Figure 3.4 DAQ Assistant

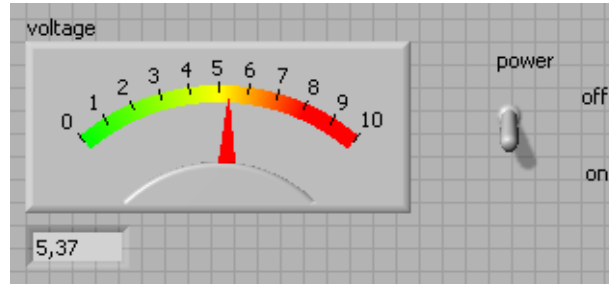


Figure 3.5 Voltage indicator

The LabVIEW graphical dataflow language and block diagram approach naturally represent the flow of your data and intuitively map user interface controls to your data, so you can easily view and modify your data or control inputs.

For experienced programmers, LabVIEW delivers the performance, flexibility, and compatibility of a traditional programming language such as C or BASIC. In fact, the full-featured LabVIEW programming language has the same constructs that traditional languages have -- variables, data types, looping, and sequencing structures as well as error handling.

3.3 More functions

· Faster Programming

Graphical Programming

Program with drag-and-drop, graphical function blocks instead of writing lines of text.

Dataflow Representation

Easily develop, maintain and understand code with an intuitive flowchart representation.

· Hardware Integration with LabVIEW

I/O and Communication

Connect to any instrument or sensor with built-in libraries and thousands of instrument drivers.

Plug-and-Play Hardware

Seamlessly integrate NI plug-and-play devices for USB, PCI, PXI, Wi-Fi, Ethernet, GPIB, and more.

· Advanced Built-In Analysis and Signal Processing

Built-In Analysis

Access thousands of engineering-specific functions such as frequency analysis, curve fitting, and more.

Inline Signal Processing

Interact with measurements and perform inline analysis in real time on acquired signals.

· Data Display and User Interfaces

Built-In Controls

Interact with data using hundreds of drag-and-drop controls, graphs, and 3D visualization tools.

Custom Controls

Easily customize the position, size, and color of built-in controls or create your own in seconds.

· Multiple Targets and OSs

Desktop and Real-Time OSs

Develop and reuse code on Windows, Mac, Linux, and real-time OSs such as VxWorks.

FPGAs and Microprocessors

Target various embedded architectures, including ARM microcontrollers and FPGAs, with the same graphical approach.

· Multiple Programming Approaches

Code Reuse

Integrate text-based code and DLLs or easily incorporate native and third-party .m files.

Various Design Patterns

Incorporate additional models of computation such as dynamic simulation diagrams and statecharts.

· Multicore Programming

Automatic Multithreading

Handle large data sets and complex algorithms faster because LabVIEW inherently runs on multiple threads.

Execution Highlighting

Easily optimize code for parallel execution using built-in debugging and visualization tools.

· Data Storage and Reporting

File I/O Designed for Engineering Data

Focus on your data and not converting formats with built-in support for a wide variety of file types.

Flexible Reporting Tools

Share your results by generating reports from your acquired data.

4. System Set-up (Hardware Description)

4.1 List of equipment

The following is a list of the equipment used. A detailed description of the most important components can be found in the next parts.

- Power Supply ($\pm 15V$)

Typ: MADS 15.1.6

A.-Nr.: 171-602-00.02

U in: 115/*230V +10/-15% 50-400Hz

I in Max.: 0.8/0.4A

KNIEL System-Electronic GmbH D-76187 Karlsruhe/Germany

IS: 16880159

- SC2000 Scan Controller Board

GSI Lumonics

IS: 03071011

- X and Y Optical Scanners

GSI Lumonics

VM-500

011-3040106

IS: 03070903/03070904

- 2 MiniSAX (Miniature Single Axis)

GSI Lumonics

Billerica, MA 01821 USA

Model Number: 002-3005051

IS: 03070905/03070906

- Laser beam

- Laser radiation avoid exposure to beam **class 3B** laser product

Iop: 1450mA

Power: $\geq 75mW$

A-A1728-0109

Laser protect glasses

Laser 2000 GmbH- TÜV ISO 9001 zert.

Laserschutzbrille Modell 426

BOL-40-426

Wareneingang: 2210921

2203002

- Laser radiation **class 2** (for safty)

- 1 Power Supply cable
- 2 Startup SAX Interface Cables, part# 712-74217
- 2 Enable Interlock SAX Interface Cables
- 2 Dual Axis Digital Servo Interface Cables
- 1 RS-232 Computer Interface Cable, part# 712-74214
- 1 Sync/Cal Ribbon Cable
- Host Computer
- NI DAQ-Card 6024E
- Terminal Block CB-68LP
- Relays
- CD of GSI Lumonics CD-ROM SC2000 CLI 2.1
- LabVIEW 2009 and DAQ driver

4.2 Optical Scanner (VM500)

The VM500 Optical Scanner (Figure 4.1) is a member of the GSI Lumonics' High Performance VM family of Galvanometers. It's designed for advanced beam and image positioning, and offer high dynamic performance along with high accuracy and instrument grade performance.

The VM Series scanners use moving-magnet design together with the newly patented capacitive position detector that offers superior accuracy.

The moving magnet technology maintains the low inertia, high rigidity and low temperature characteristics of the M series predecessors, while allowing for increased bandwidth. This enables the scanner to move at higher speeds with more precise angular positioning.

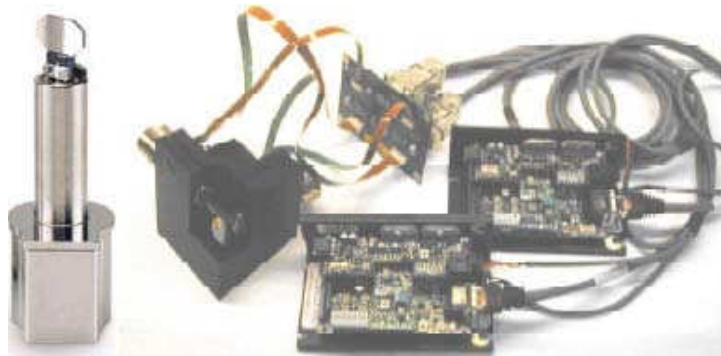


Figure 4.1 Optical scanner and control electronics

The VM Series Scanners are optimized for both large and small signal applications, and provide improved drift, noise, and linearity.

Highest performance is achieved when the VM Galvanometer is mated with GSI Lumonics' newly designed mirror assemblies and an optimized GSI servo controller.

When the thermal control option is purchased with the complimenting servo driver, the built-in thermal blanket around the position detector that is a standard feature of all VM Series Galvanometers can be used to maintain a specific temperature, in order to eliminate temperature-related drift.

Using the thermal control option of the VM series scanners minimizes scanner offset and gain drift. The set point for temperature-regulated scanners must be above the highest expected ambient temperature but not above 50° C. For maximum stability, temperature controlled scanners may require thermal isolation from the scanner mount so that heat sinking by the mount does not interfere with temperature regulation.

Standard Mirrors (clear aperture)		Maximum Scan Angle
VM500	4mm	±30° Optical
	5mm	±25° Optical
	6mm	±20° Optical

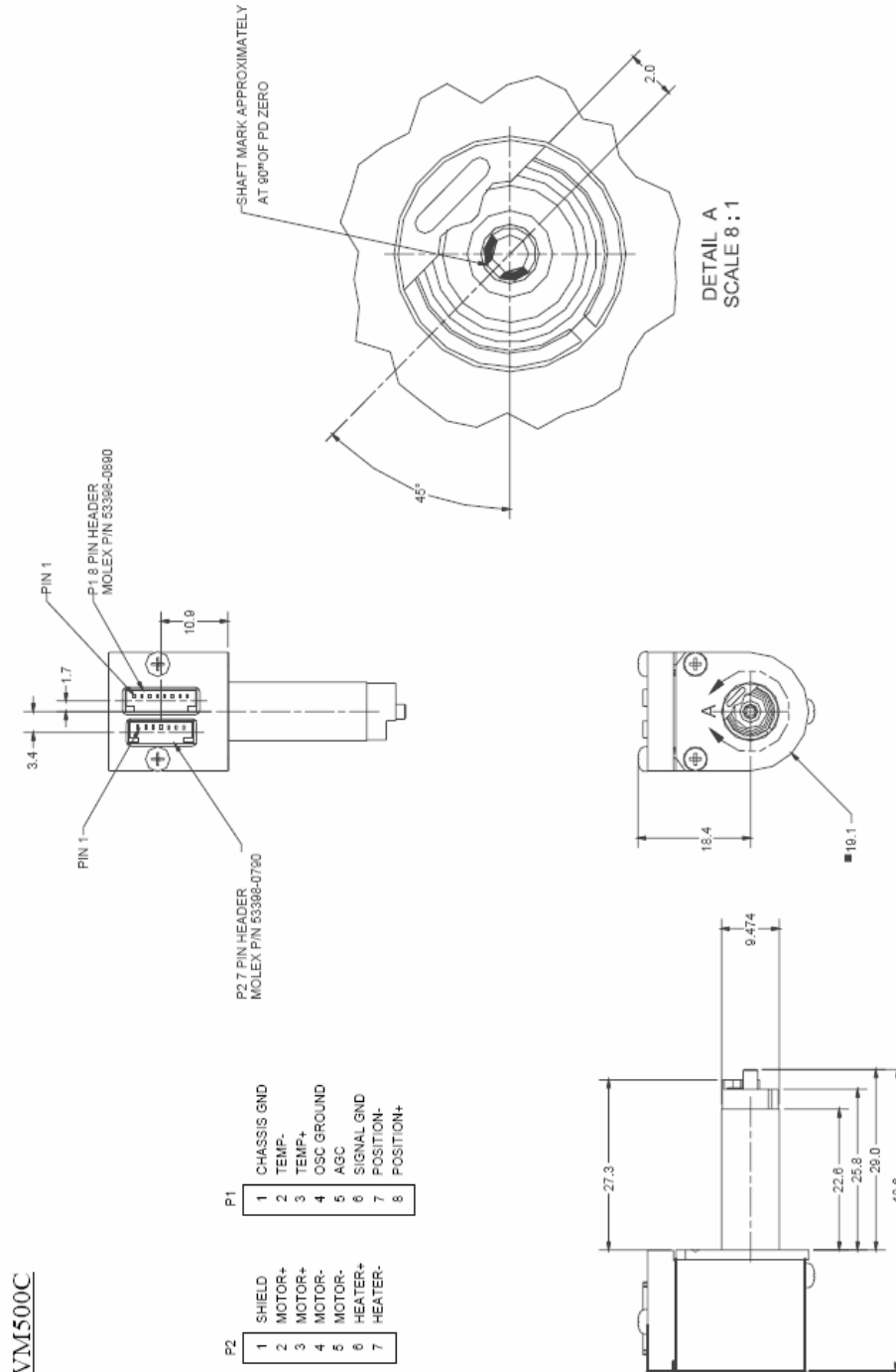


Figure 4.2 Geometrical dimension and pinout

Figure 4.2 shows geometrical dimension and pinouts. The maximum scan angle is 30° and it can scan maximum 32768 x 32768 positions.

4.3 Mini SAX

The MiniSAX (Miniature Single AXis) servo controller (Figure 4.3) is one of GSI Lumonics' most recent developments in galvanometric servo control technology. By taking advantage of the newest surface mount components, the MiniSAX provides full-function scan electronics at a size and cost less than many stripped down servo amplifiers. Advanced servo filtering techniques together with a low-coupling design provide extended bandwidths and improved response times. The MiniSAX was engineered with system designers in mind, incorporating a simple yet comprehensive and flexible interface structure. For the first time, laser system manufacturers can purchase a truly high performance, cost effective galvanometer servo controller that allows convenient, "in-head" packaging.

The MiniSAX uses a modular design, providing the ability to readily configure the driver for specific applications. An optional filter module is available in a variety of adjustable notch frequency ranges. The frequency response of this module can be optimized to handle a variety of customer-supplied loads. A thermal control module is available to support GSIL's thermally regulated scanners, allowing use of the industry's lowest drift galvanometers.

The MiniSAX product line includes a variety of accessories that ease the integration into your manufacturing process. The MiniSAX mounting bracket provides convenient mounting surfaces and mates with either of two optional heatsinks. A test interface board allows easy access to a variety of important test points. Mating connectors and inexpensive assembly tools are available directly from GSI Lumonics. The MiniSAX Startup Kit is recommended for first time users and includes many of these valuable accessories.



Figure 4.3 Mini SAX

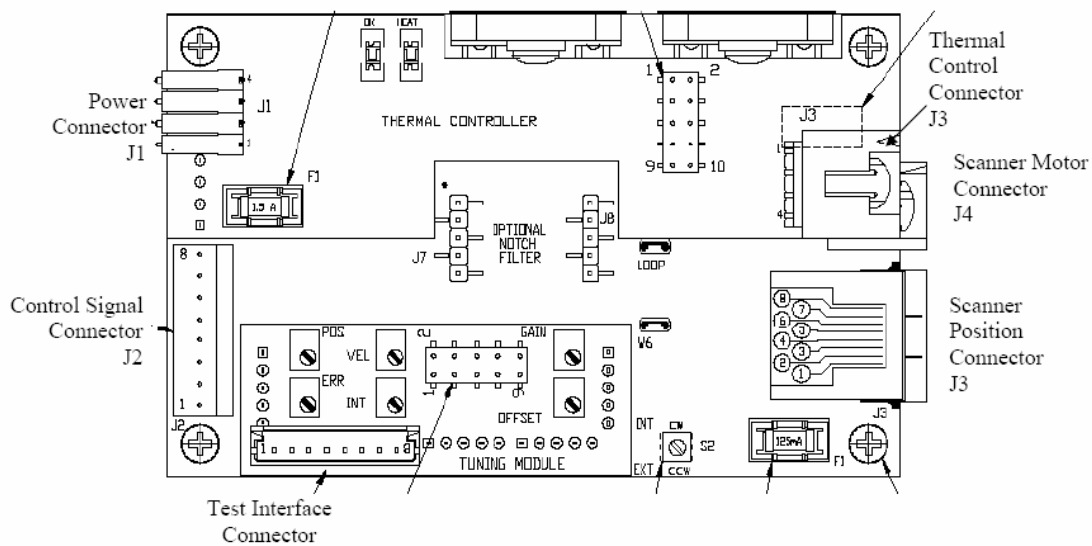


Figure 4.4 Mini SAX connections

4.4 GSI Lumonics SC2000 Digital Scan Controller

The SC2000 Scan Controller (Figure 4.5) is designed to provide fast, accurate, user-friendly control over GSI Lumonics' MiniSAX and Dual Axis Digital servo amplifiers and associated peripherals. Using either the provided GSI Lumonics Command line interface software, or similar user-designed software, the controller can be programmed to operate in conjunction with a host computer or in a stand-alone configuration. The stand-alone configuration allows the user to run a series of programs, from non-volatile memory upon system power up, as well as trigger program execution using control input and output signals. Interfacing with a host computer, on the other hand, allows the user to choose a mode of operation, between the controller and the host, ranging from totally autonomous to tightly coupled.

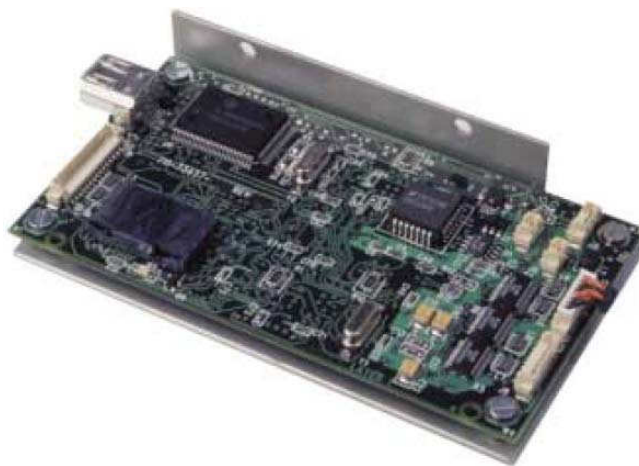


Figure 4.5 SC2000 digital scan controller

The Scan Controller interfaces directly to the position command, position feedback, and binary communications of the servo amplifiers. This allows for full position control of the system and control of the enable/status interlock between the SC2000 and driver board. Likewise, this interface allows the user to monitor position feedback from the galvo, as well as read calibration information digitally via the host computer.

In addition to controlling the servos, the Scan Controller has hooks to aid in the interface and control of other peripherals typically associated with scanning systems. These include sync inputs and outputs, a pixel clock system, a calibration/data capture system, and other functionality available to volume OEM system designers.

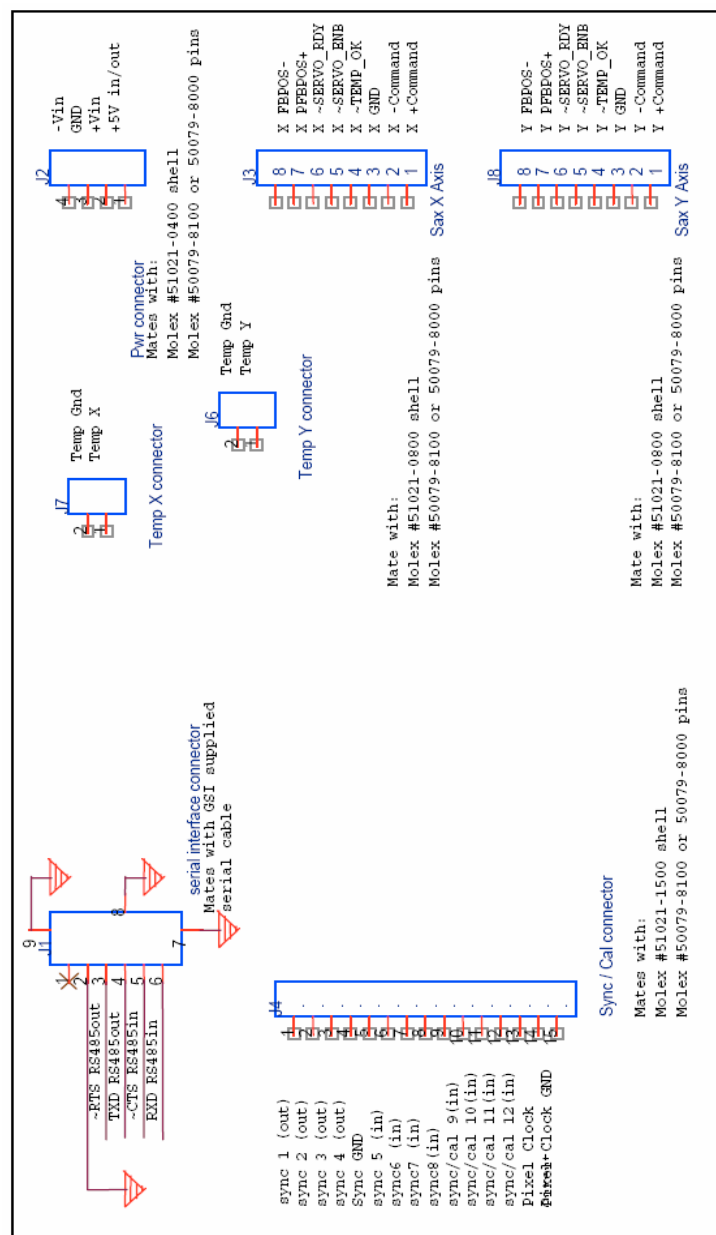


Figure 4.6 Pinout of scan controller

4.5 Laser

In this project lasers of class 2 and 3B have been used. The definition of these laser classes are given below:

Class 2:

Low risk to eyes. No risk to skin

Class 2 laser products are defined as those emitting visible light for which the natural aversion response to bright light (including the blink reflex) prevents retinal injury, including direct viewing of the laser beam with optics that could concentrate the laser output into the eye. These lasers do, however, present a dazzle hazard.

Lasers that were Class 2 under the previous version of 60825-1 remain Class 2 under the new scheme.

Warning label: DO NOT STARE INTO BEAM

Only use Class 2 for safety during the experiments in room.

Class 3B:

Medium risk to eyes. Low risk to skin

Class 3B laser products are defined as those for which direct exposure of the eye is hazardous, even taking aversion responses into account, but scattered laser light is usually safe. The higher power Class 3B lasers are also a skin hazard, but the natural aversion response to localised heating generally prevents a skin burn. Lasers that were Class 3B under the previous version of 60825-1 but which operate at a wavelength in the range 0.3025 to 4 μm and have output beams that are either high divergence or large diameter may qualify.

Warning label: AVOID EXPOSURE TO THE BEAM

In the project two different lasers are used. Class 2 laser is used to test the position of laser and class 3B laser is used to scan the image plate. Because class 2 laser is safe and it is weak to exposure photons.

4.6 Hooking up the system

The components of the system are connected according to the user manual.

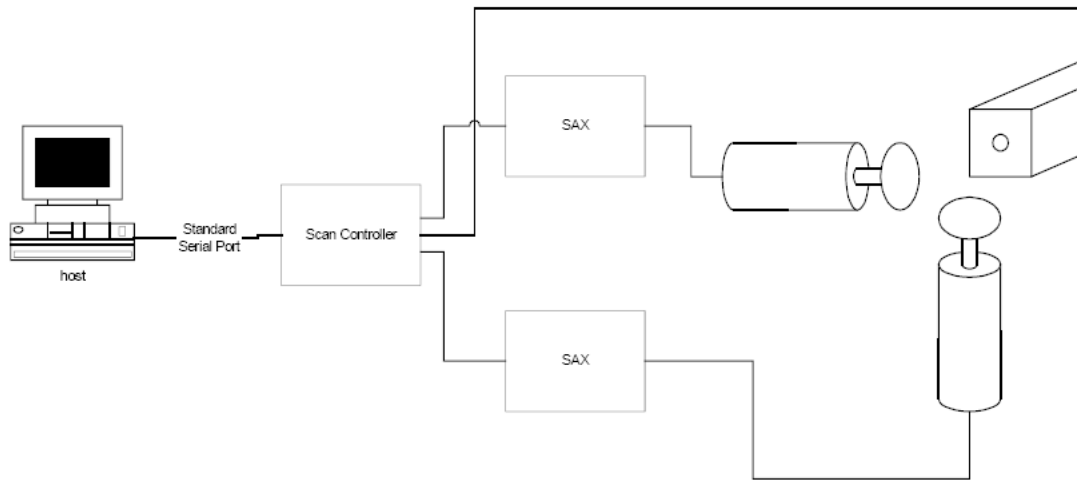


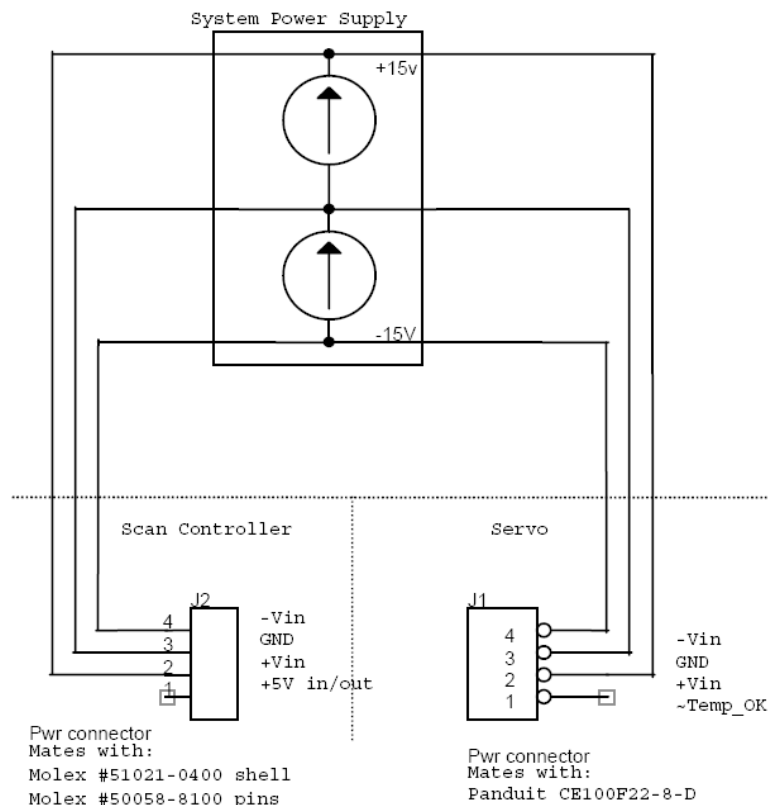
Figure 4.7 System connection

Step 1 Before you begin:

- Be sure power supply is turned off.
- Be sure make all connections firmly. Loose connections may cause communications and/or performance problems.
- Be sure wearing a properly grounded wrist strap or heel strap. Components on the SC2000 Controller board are highly sensitive to electrostatic discharge.

Step 2 Connecting the Power Supply:

- Using the provided power cable, connect the stripped leads to the power supply terminals as labeled:
+15V to the positive supply terminal
COM to the common terminal
-15V to the negative supply terminal
- Plug the power cable's Molex connector into the pwr connector, J2, on the SC2000 controller board.



Step 3 Connecting the servo Interface Cables:

For the MiniSAX servo amplifier:

- Using a Startup SAX Interface Cable (part numbered 712-74217), connect the X axis interface (J3) on the SC2000 to the X axis MiniSAX command interface (J2 on the SAX board).
- Use the remaining Startup Interface Cable to connect the Y Axis interface (J8) on the SC2000 to the Y axis MiniSAX command interface (J2 on the SAX Board).
- Connect the X axis controller command interface, J3 on the SC2000, to the X axis servo command interface (J3 on the underside of the Digital Servo).
- Use the remaining command cable to connect the Y axis command interface, J8 on the SC2000 to the Y axis servo command interface (J4 on the underside of the of the Digital Servo).

Step 4 Connecting the Host Computer:

- Connect the provided Computer Interface Cable (part number 712-74214) to an available serial port on your host computer. Remember which serial port you use since you will need to know which port to address when communicating with the controller board. Connect the other end of the cable to the Serial Interface connector (J1) on the controller board.

Step 5 Sync/Cal Connections (Optional):

The Sync/Cal connector provides access to the synchronization /calibration I/O as well as the pixel clock output of the Scan Controller. Figure 3 shows a system using one of the (open drain) sync outputs and the auxiliary +5V output to power and control a diode laser module.

For further information on the Sync/Cal and pixel clock features of the scan controller, read the GSI Lumonics Scan Controller Users Manual.

For controlling a low power laser diode module:

- Connect laser diode (+) output to +5V output (J2, pin 1) of the Scan Controller.
- Connect laser diode (-) output to sync gnd (J4, pin 5) on the Scan Controller.
- Connect laser diode modulation control output to sync 1 (J4, pin 1) on the Scan Controller.

Note: User must supply a 4.7k pull up resistor between the +5V and Sync 1.

There are other ways to interface to a laser. For example connect the + lead to +5V and the – lead to the sync pin. This would be good enough for users who don't need high performance switching.

Warning: Check the manufacturer's voltage and current specifications before hooking up a laser diode or any other peripheral. The open drain outputs on the Scan Controller (sync 1–4) are specified to sink up to 100mA continuous, and withstand peaks up to 40 V. These output must be clamped if inductive loads are to be driven (i.e. a small relay). Otherwise, the voltage transient generated at turn-off can destroy the sync output transistors.

Step 6 Software Installation:

The GSI Lumonics Command Line Interface software discussed in the manual can be found on the provided CD-ROM. Read the ReadMe.txt file for the latest information and changes.

- To install the software run '`<CDROM> :\\install\\disc 1\\setup.exe`'. The setup program will create a default installation directory (typically C:\\GSI), install the application and support files and peripheral tools, create a program group and add an item in the Windows start menu.
- If using a Servo/Galvo pair, connect galvo to driver board.

Step 7 Final Setup:

- If using a Servo/Galvo pair, connect galvo to driver board.
- Double check all connections to make sure they are correct and secure.

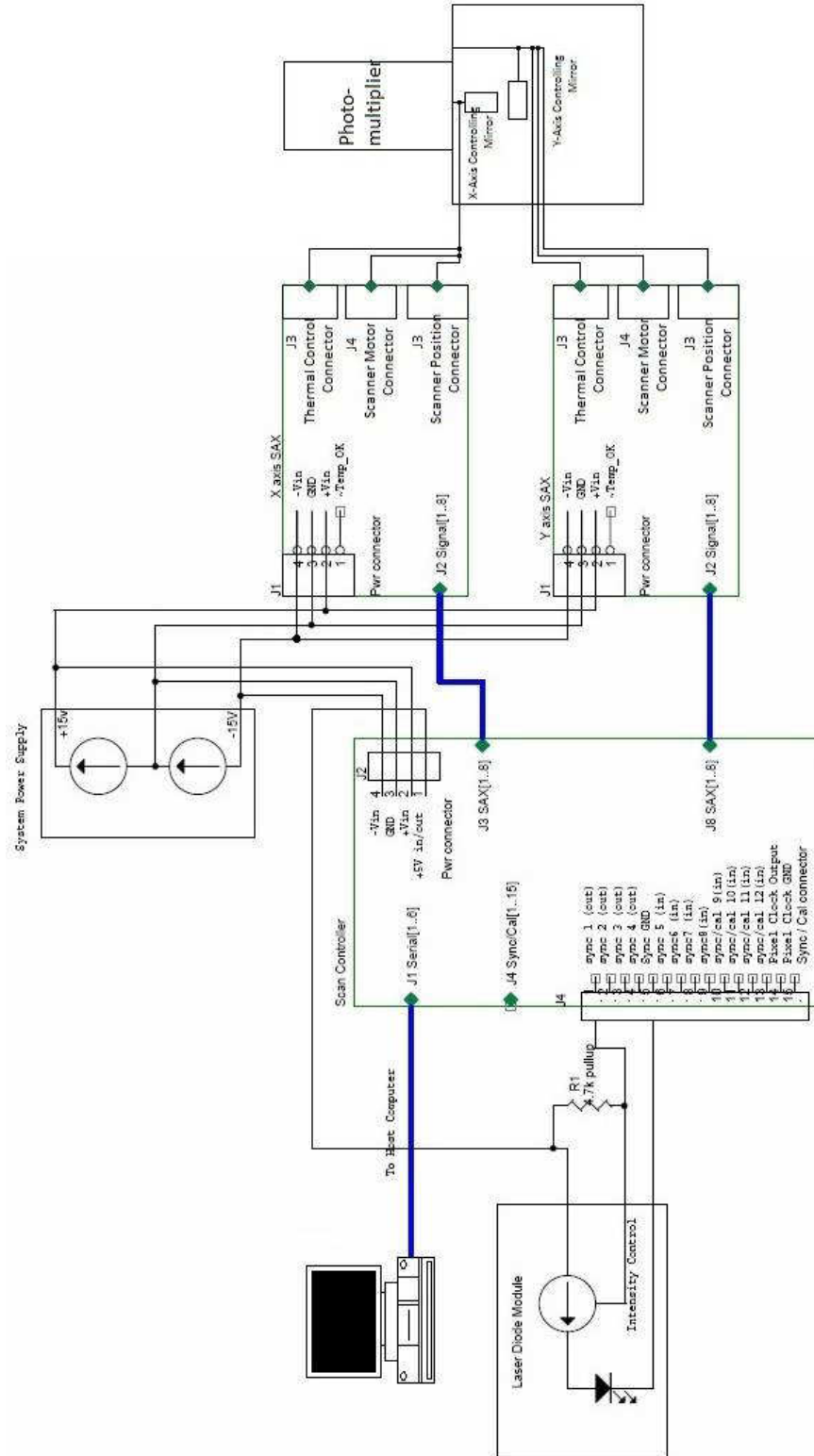


Figure 4.8 Detailed system connection

4.7 Control of laser, lamp and photomultiplier tube

The other circuit controls other hardware, such as laser, lamp and photomultiplier tube that are controlled by DAQ-Card, terminal block and relays.

4.7.1 DAQ-Card 6024E



Figure 4.9 DAQ-Card 6024E

The National Instruments PCI-6024E shown in figure is a low-cost data acquisition board that uses E Series technology to deliver high-performance, reliable data acquisition capabilities in a wide range of applications. You get up to 200 kS/s sampling and 12-bit resolution on 16 single-ended analog inputs. Depending on your type of hard drive, the NI PCI-6024E can stream to disk at rates up to 200 kS/s.

With this we can get data and signals or produce signals to terminal block. Also it can measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer.

AI 8	34	68	AI 0
AI 1	33	67	AI GND
AI GND	32	66	AI 9
AI 10	31	65	AI 2
AI 3	30	64	AI GND
AI GND	29	63	AI 11
AI 4	28	62	AI SENSE
AI GND	27	61	AI 12
AI 13	26	60	AI 5
AI 6	25	59	AI GND
AI GND	24	58	AI 14
AI 15	23	57	AI 7
AO 0	22	56	AI GND
AO 1	21	55	AO GND
NC	20	54	AO GND
P0.4	19	53	D GND
D GND	18	52	P0.0
P0.1	17	51	P0.5
P0.6	16	50	D GND
D GND	15	49	P0.2
+5 V	14	48	P0.7
D GND	13	47	P0.3
D GND	12	46	AI HOLD COMP
PFI 0/AI START TRIG	11	45	EXT STROBE
PFI 1/AI REF TRIG	10	44	D GND
D GND	9	43	PFI 2/AI CONV CLK
+5 V	8	42	PFI 3/CTR 1 SRC
D GND	7	41	PFI 4/CTR 1 GATE
PFI 5/AO SAMP CLK	6	40	CTR 1 OUT
PFI 6/AO START TRIG	5	39	D GND
D GND	4	38	PFI 7/AI SAMP CLK
PFI 9/CTR 0 GATE	3	37	PFI 8/CTR 0 SRC
CTR 0 OUT	2	36	D GND
FREQ OUT	1	35	D GND

NC = No Connect

Figure 4.10 NI 6024E Pinout

4.7.2 Terminal block CB-68LP

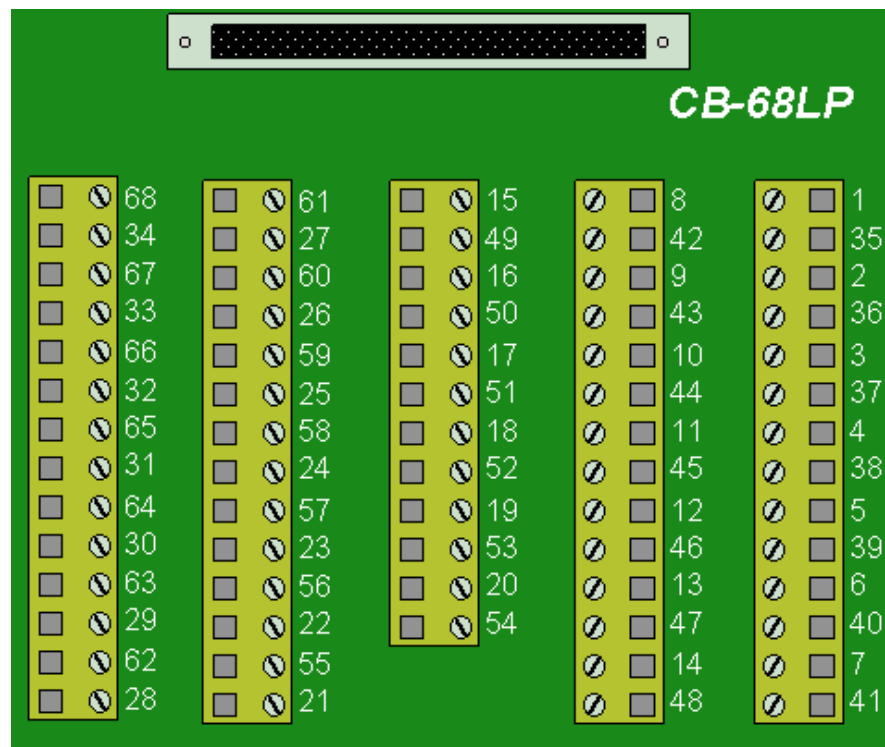


Figure 4.11 Terminal block CB-68LP

The NI CB-68LP is a low-cost termination accessory with 68 screw terminals for easy connection of field I/O signals to 68-pin data acquisition products. It includes one 68-pin male SCSI connector for direct connection to 68-pin cables. The connector blocks feature standoff feet for use on a desktop or mounted in a custom panel. The CB-68LP has a vertical-mounted 68-pin connector.

It is connected with DAQ-Card and these 68 pinouts are the exactly same as DAQ-Card pinouts above. It is one “magnification” of DAQ-Card pinouts.

For example, we use Digital Output to control laser, lamp and photomultiplier tube. And we use Counter to measure the number of pulse in the limited time.

4.7.3 Relays

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it

to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

We connect relays to terminal block which provides about 5V for pins when they are open. The relays for laser and lamp are connected to the Digital Outputs of the terminal. We give a True signal to Digital Outputs by LabVIEW to open these pins. They provide 5V and so relays are closed and outputs of relays are connected. So the laser and lamp are open. For photomultiplier tube we use external input instead of use internal input (220V). It works when we supply only 5V to the external input. So we use relay in the opposite way. When we give a True signal to Digital Output of the terminal block, it would be closed and output of relay is connected. It means no voltage at output of relay. So photomultiplier tube is off. When we give a False signal to Digital Output of the terminal block, it would be opened and output of relay is disconnected. It means there is 5V at output of relay. So photomultiplier tube is on.



Figure 4.12 Relays (left from ABB, right from PhoenixContact)

4.7.4 Circuit connection

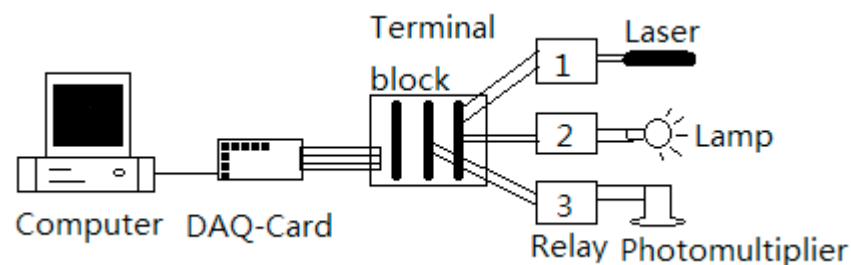


Figure 4.13 Circuit connection

The figure 4.13 shows circuit connection. The DAQ-Card is inserted in the computer. And it is connected terminal block. There are three relays to control laser, lamp and photomultiplier. Each relay is connected with different digital output of terminal block.

Table 4.1 Status of digital outputs, relays and components

Digital output for	Status of output	Relay	Component
Laser	on	connected	on
	off	disconnected	off
Lamp	on	connected	on
	off	disconnected	off
Photomultiplier	on	connected	on
	off	disconnected	off

The table 4.1 shows status of digital outputs, relays and components.

Digital Output for laser is on, relay is connected, laser is on. Digital Output for laser is off, relay is disconnected, laser is off.

Digital Output for lamp is on, relay is connected, lamp is on. Digital Output for lamp is off, relay is disconnected, lamp is off.

Digital Output for photomultiplier tube is on, relay is connected, no voltage between outputs of relay, photomultiplier tube is off. Digital Output for photomultiplier tube is off, relay is disconnected, 5 voltage between outputs of relay, photomultiplier tube is on.

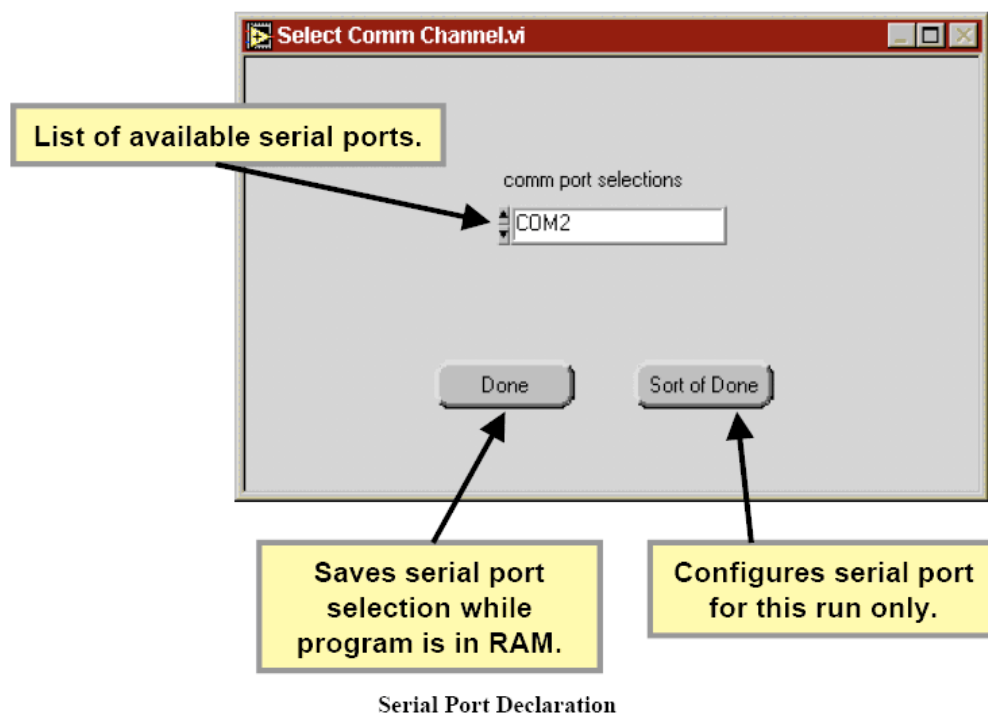
It is important that the relay for photomultiplier is used in the opposite way. Because high voltage transformer needs external power to supply high voltage (1kV) to the photomultiplier.

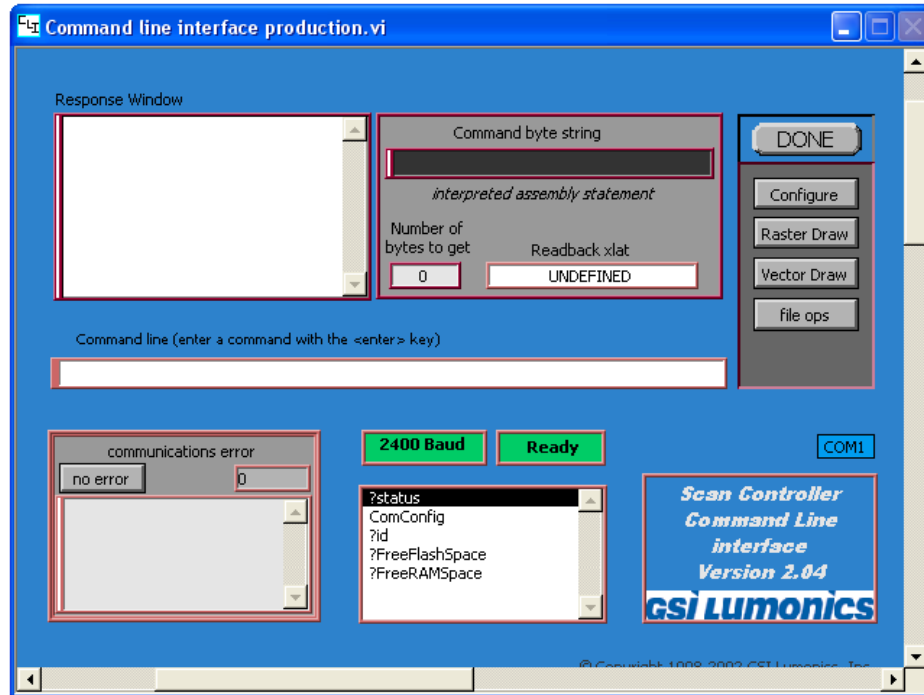
5. Scan controller support software

5.1 Introduction of the Support Program

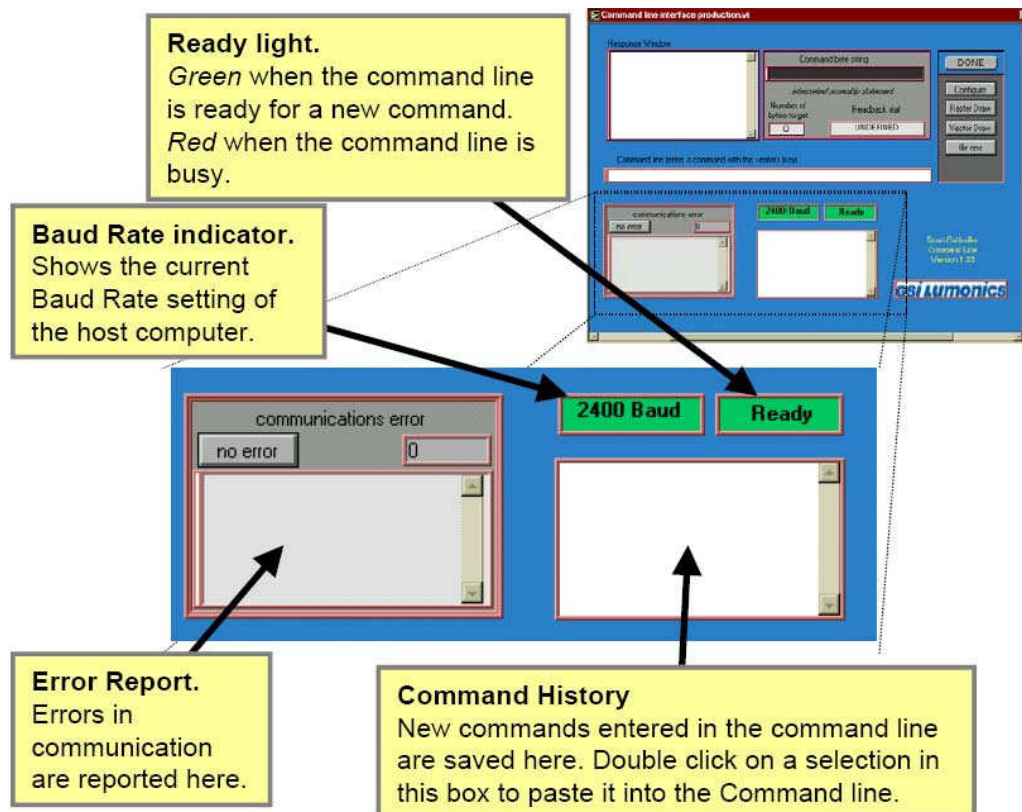
The Command Line Interface software written in LabVIEW allows users to communicate with the Scan Controller quickly and easily. It is intended primarily as an environment for designing and programming stand-alone applications, and for system evaluation. Using Command Line Interface software during system evaluation provides a user-friendly learning environment in which functional capabilities of the Scan Controller can be understood and applied. Once the functionality and limitations of the Scan Controller are understood, designing host-based, real-time system programs becomes much easier. While pieces of the provided code can be utilized in host-based, real-time systems, that is not its primary intent.

When you start to run the CLI.exe, it will automatically raise the Serial Port selector sub-window asking you to set the serial port device for Scan Controller communication. Choose one COM that was used and press 'Done' to enter your serial port.

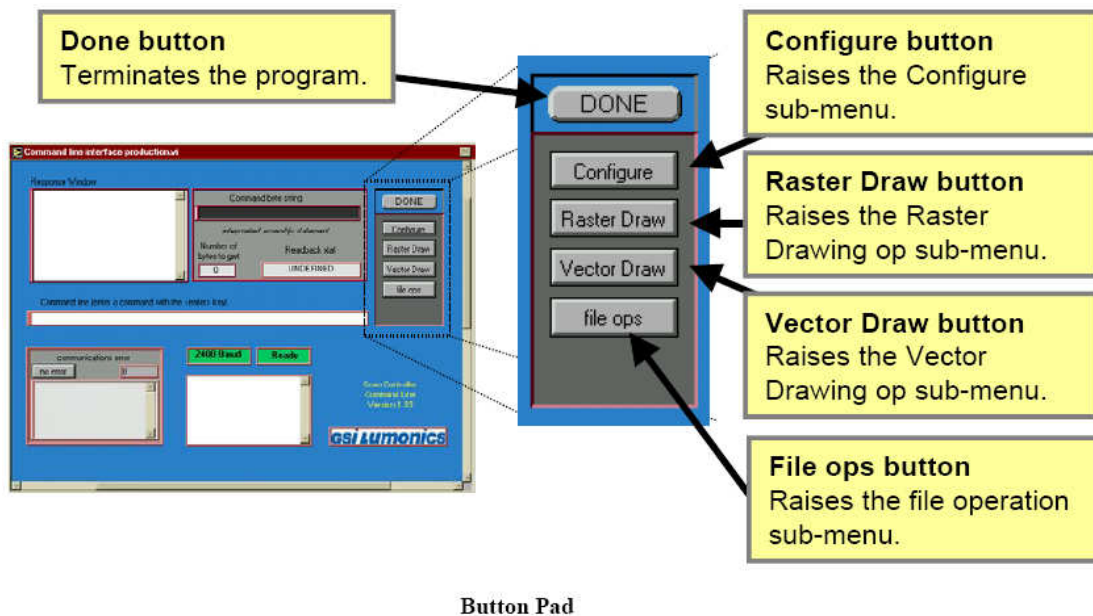
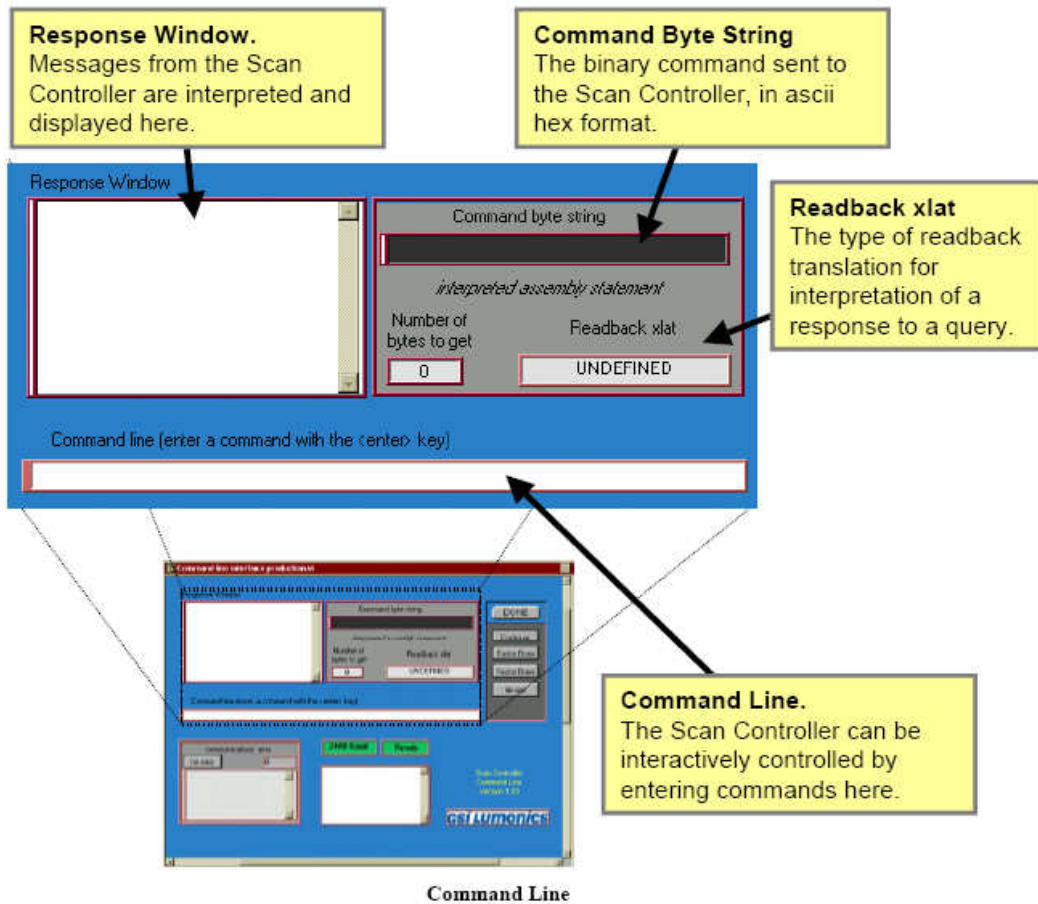




Here is the main Functions of the Command Line Interface Main Window:



Status Displays



5.2 Command Reference

The Command Line Interface (CLI) and the Motion Assembler Component (MAC) incorporate assemblers that translate English language program commands into the binary language of the SC2000. Each command is defined in the assembly language context and then in the binary context, but note that the SC2000 will only accept commands uploaded in the binary format.

In order to exert the program efficiently we need to be familiar with the Commands of the program especially these in boldfaced that will be used in the project.

For more commands see appendix.

Explanation of operational modes

Overview: There are various modes of operation that overlap or are mutually exclusive depending upon those compared.

Raster Mode: A fundamental operating mode for either programs or immediate instructions in which all motion commands are directed to a specified axis.

Vector Mode: A fundamental operating mode for either programs or immediate instructions where motion commands are simultaneously directed to the both X and Y axis.

Program Instruction Mode: When a program is running the operational context of the instructions of the program will be Program Instruction Mode. In contrast, query commands and the system configuration commands cannot be executed from a program, i.e. they are not valid in Program Instruction Mode.

Immediate Instruction mode: This is the idle mode of the Scan Controller, when a program is not running. Typically, every command can be executed from this mode except those that deal exclusively with the operation of programs, i.e. Repeat, Nrepeat, End, and ExecuteSerialNumber.

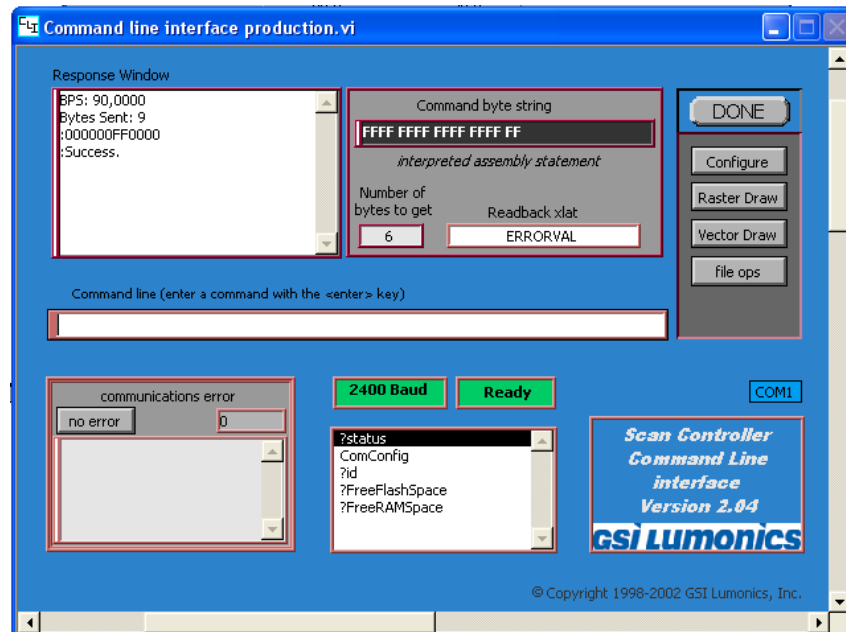
Dual Single Axis: This mode is only available when the ExecuteRasterPgm command is executed. This mode is characterized by two raster programs running concurrently, one on each axis.

Concurrent Instruction mode: This mode comes about when a program is running and you try to enter a command over the communications interface. Typically, commands valid for this mode are the query commands, AbortPgm and ExitPGM.

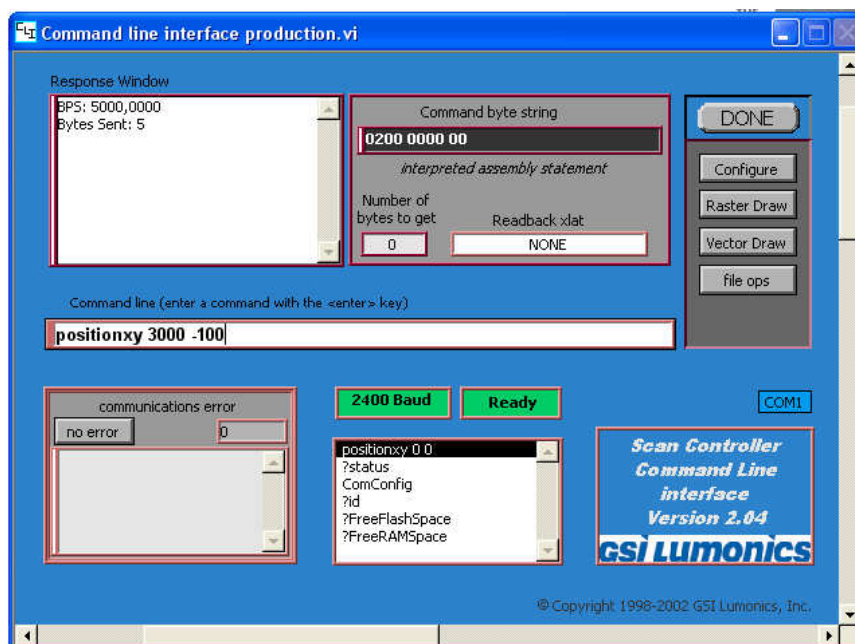
5.3 Operation for Scan controller

To be familiar with the software commands, several basic operations have been performed by using the command line interface (CLI).

1. Use the command '?status' to make sure there is no errors with the system. 'Success' will be shown in the Response window.



2. Fix the laser beam in a proper location, check the position and the direction of the scanning point.



3. To correct the position and the direction of the moving point, we need to know how many degrees should be turned and how many steps should be changed to the 0 point. Then use the 'rotate calculator' to get the commands. After these commands entered into the command line the coordinate of the laser beam will just changed to fit the image plate.

As the image plate in our experiment is oriented an angle of 45° , the relation between the X and Y coordinate and the angle positions of the mirrors depend on the coordinates. The necessary corrections can be obtained using the "rotate calculation".

In fact the orbit of scan is a curve because of degrees between mirrors and image plate. It is too complicate to calculate correct position for each point to make linear orbit. So we make the curve to line (Figure 5.1). It is easy to calculate how much distance y-axis mirror should move. The maximum distance between ideal orbit and real orbit d divided by l is the slope of the line. With it we can calculate how much distance y-axis mirror should move.

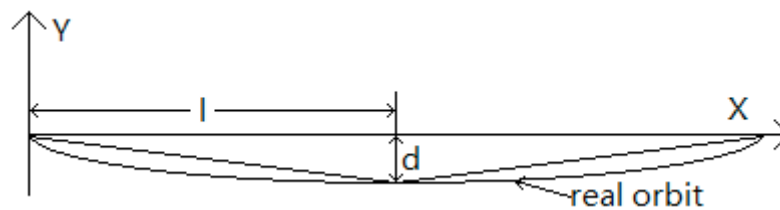


Figure 5.1 simplify of scan orbit

The project is to scan a max. 500mm×500mm large area neutron image plate every 1mm grid with the laser beam. But for experiment we use 10cm×10cm large area by every 1cm grid as a first step (Figure 5.2).

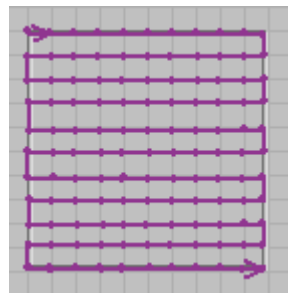
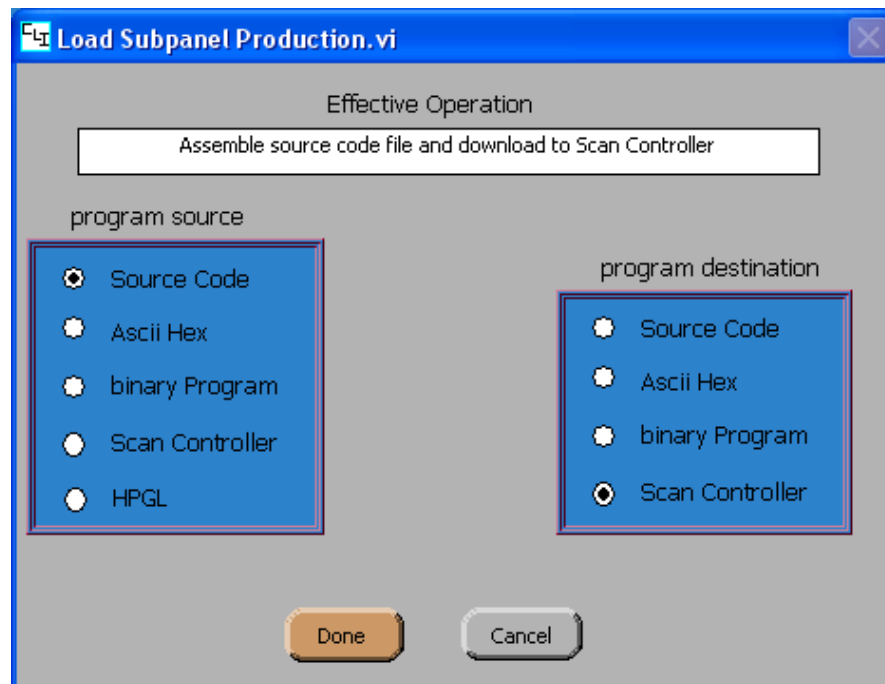


Figure 5.2 Ideal scanning orbit

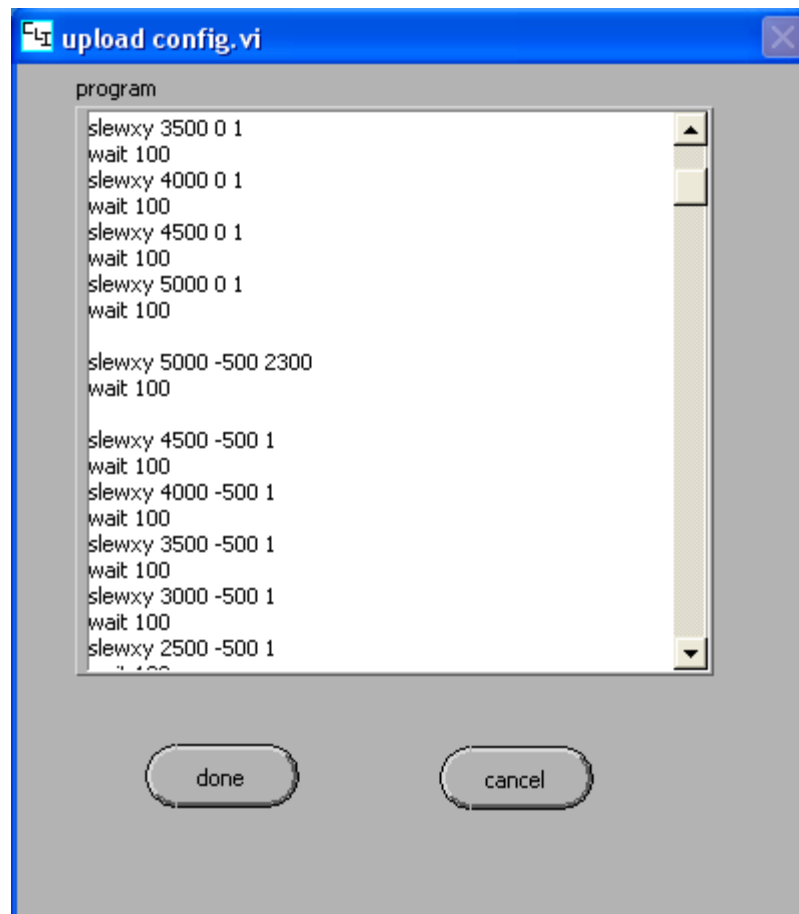
The following program performs this scan.

```
CreatePGM 1 'a'           //create a task
Setsync 1                 //laser is on (1 means laser is open)
wait 100
slewxy 500 0 1            //scan to position (500,0) with open laser
wait 100                  //wait 100ms
slewxy 1000 0 1
wait 100
.....
wait 100
slewxy 4500 0 1
.....
slewxy 4000 -5000 1
wait 100
slewxy 4500 -5000 1
wait 100
slewxy 5000 -5000 1
wait 100
positionxy 0 0           //go back to default 0,0 position
wait 100
repeat
end
```

- Save program as a .txt file in the desired directory. Running the Vector Mode Program
- Click on the [File Ops] button in the Main Program Window of the Command Line Interface.



- In the Load Subpanel, select 'Source Code' as the Program Source and 'Scan Controller' as the Program Destination. Press Done.



- In the File Dialog box, select the saved .txt program. Press 'OK'. This brings up the Upload Configuration Sub-window shown below. This window provides a type of stream editor where it is possible to change commands, add or remove lines or change the name of a program without changing the original source file.

- To assemble and upload the program click (Done). The program is then automatically assembled and uploaded into the Scan Controller. If the assembler detects an improperly formatted command in the program, assembly is halted and an error message is returned to the Main Program Window. If this occurs, correct the error in the text file and then reload the program. While the program is being assembled and uploaded, the Command Line 'Ready' indicator switches from green to red and indicates that the command line is Busy. Assembly and Uploading information is provided in the Response Window.

- Once the upload is complete, and the Command Line 'Ready' Indicator turns green, execute the program. In the Command Line Window, enter: Executepgm 'a'

The Scan Controller will then begin running the uploaded program and sending commands to the servo drivers.

If nothing happens after entering the Executepgm command:

- Check Scan Controller servo Interface connections.
- Be sure power is applied to servo boards and that galvos are properly connected.
- Execute a ?Status Query to check for possible communications failure.
- Make sure that 'a' was typed in quotes

To Stop Program:

ExitPgm acts as a soft stop and will run through the remainder of the program before stopping.

AbortPgm terminates the program immediately.

5.4 Application

Command Line Interface also has many other functions, such as scan a circle track (Figure 5.3) or even Letters in different fonts. Because the Optical Scanner moves quite fast so it seems to be coherent lines.

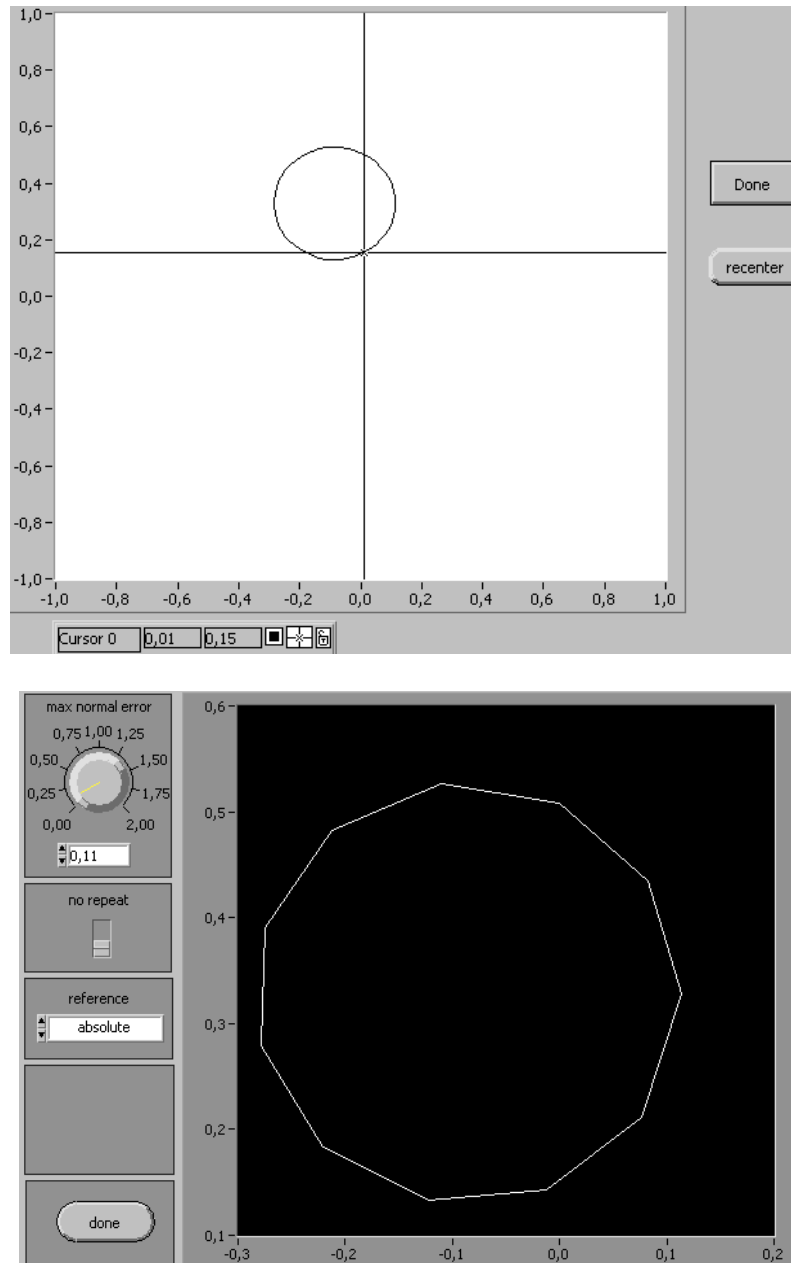


Figure 5.3 Example of other function

6. Own LabVIEW Interface

6.1 The whole program

This program is based on queue structure which is called Producer/Consumer Design Pattern. Use this template to build a producer/consumer design pattern with events to produce queue items. Use this design pattern instead of the User Interface Event Handler pattern for user interfaces when you want to execute code asynchronously in response to an event without slowing the user interface responsiveness. It is made up of several parts such as data acquiring, 2D-Array, intensity graph processing and so on.

The figure 6.1 shows front panel of the interface. It is composed of switches, graphs, LEDs, and other controls and indicators. The detailed functions will be found in next parts.

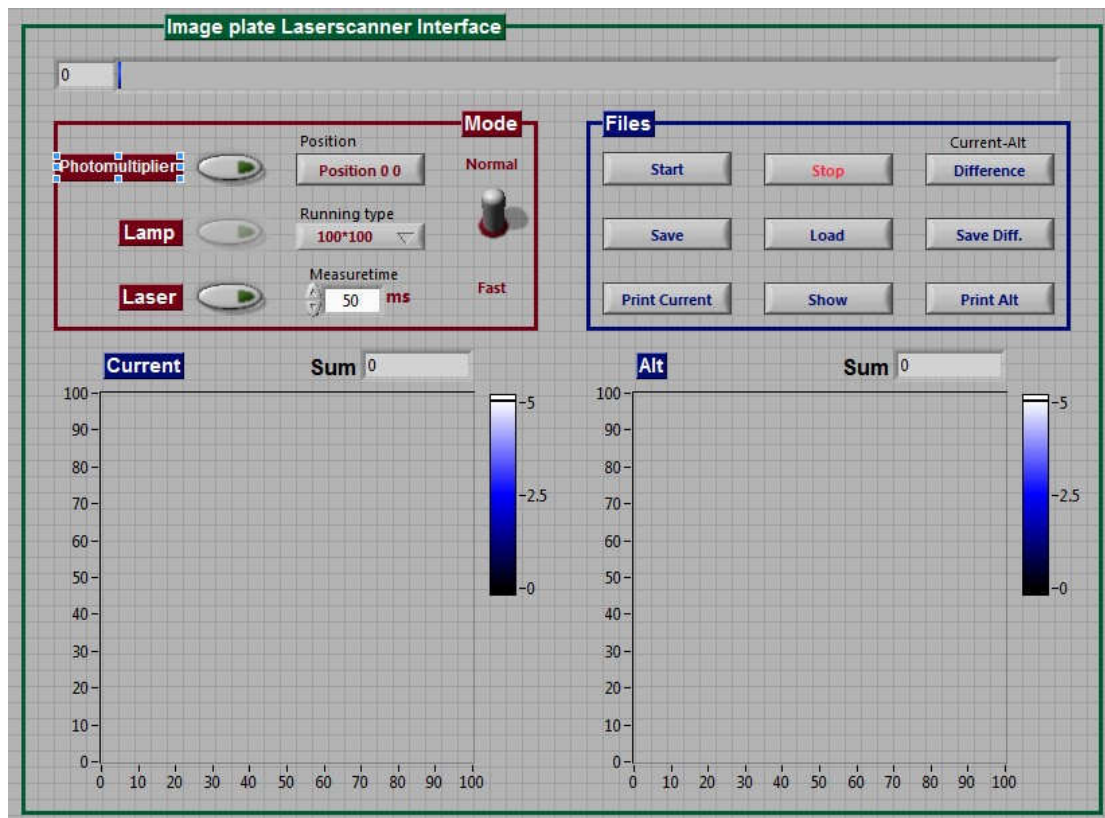


Figure 6.1 Front panel of the interface

The figure 6.2 shows block diagram of the interface. In G language, the block diagram, which consists of executable icons, called nodes, and wires that carry data between the nodes, is the source code for the VI.

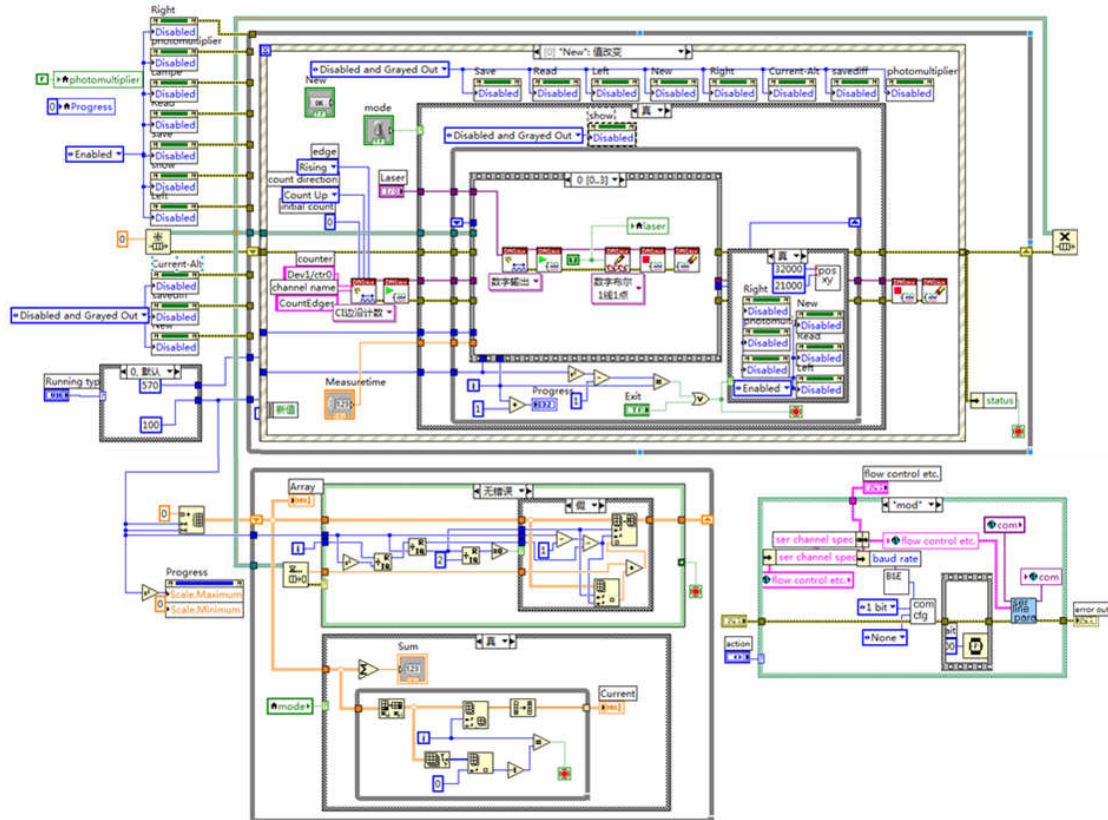


Figure 6.2 Block diagram of the interface

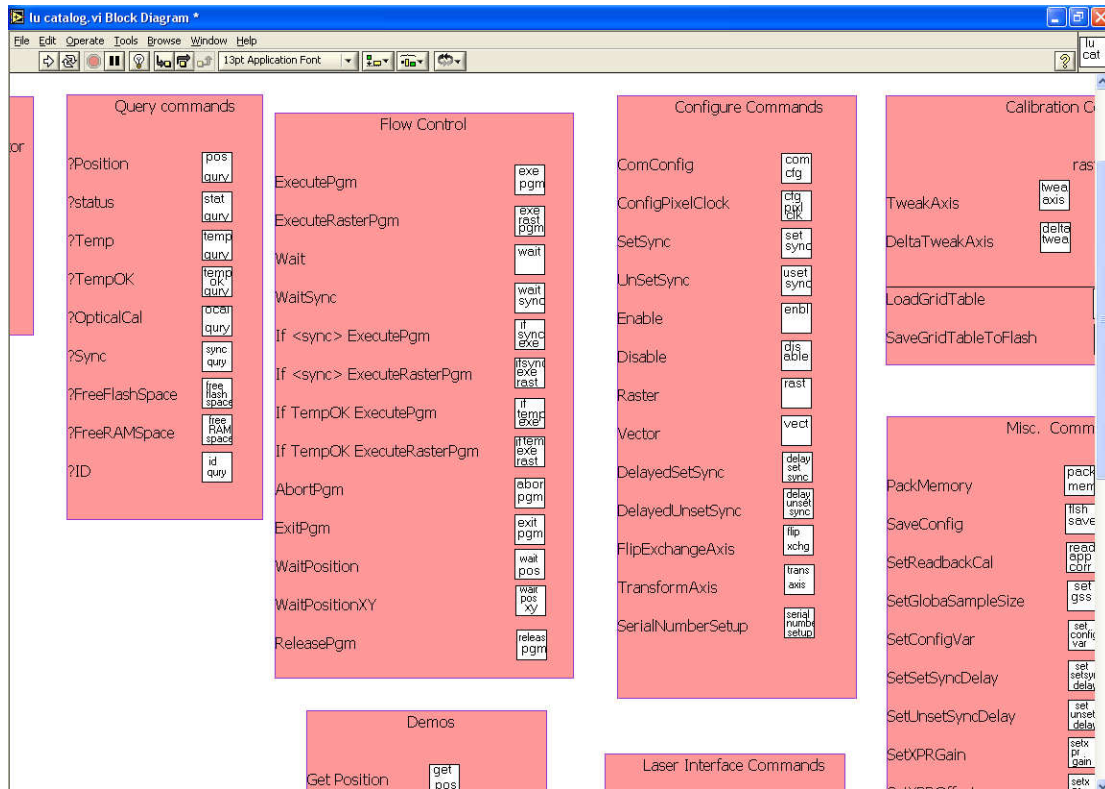


Figure 6.4 catalog in block diagram

6.2.2 ComConfig set

Configure the baud rate, parity and stop bits settings of the RS-232 connection between the host computer and the Scan controller. Changes will be reflected both the Scan Controller and the host computer.

The figure 6.5 shows settings of baud rate, parity and stop bits. It can be found in SubVIs from SC2000 driver.

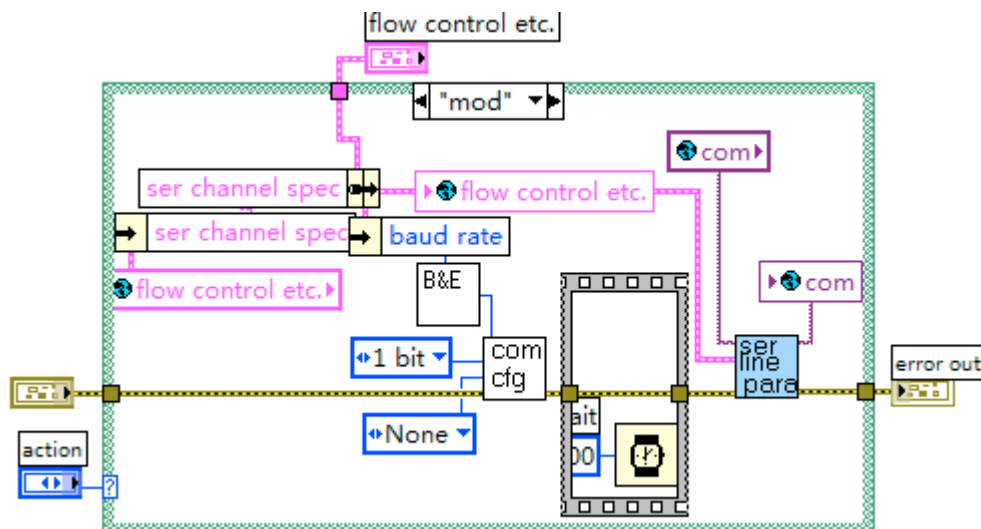


Figure 6.5 Settings of baud rate, parity and stop bits

The default baud rate setting for RS-232 communication between the Scan Controller and the Host computer is 2400. RS-232 supports baud rates up to 115200. If the Command Line program is shut down, it will restart in its default setting of 2400 Baud. Likewise, if the Scan Controller is power cycled, it will power up at its default baud rate of 2400. If you choose to use a higher baud rate, you must reconfigure the system every time when the program is restarted or the Scan Controller is power cycled. Failing to do so will result in a communications error.

6.2.3 Correction of the Laser Position

The command Position 0 0, which used to correct the Laser position can be written into the G language. It works with the SubVIs. It takes the laser to (0, 0) position before we start to scan.

6.3 Data process

Click START button to scan the image-plate. When the scan is finished, we can save the data or the intensity graph. Also we can scan more times just by click START button. It makes automatically the position of laser to (0, 0) and start to scan. The numbers in the array are not new value, but they are numbers which are added by old and new value.

6.3.1 Mode and files options

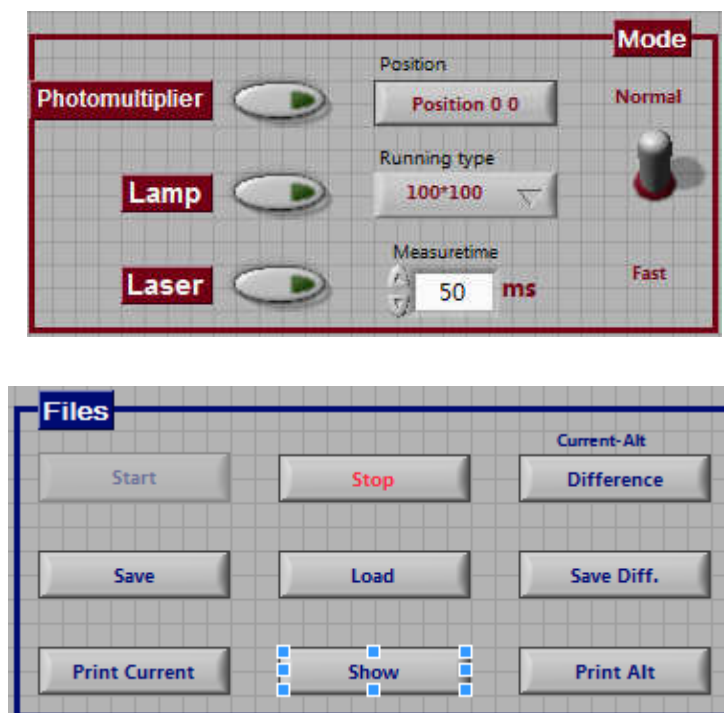


Figure 6.6 Front panel of mode and file options

The figure 6.6 shows front panel of mode and file options. We have two modes to scan Image-Plate, NORMAL and FAST mode. For the running type we can choose 100mm*100mm or 10cm*10cm. The default measuring time is 50ms. It means the laser is open for 50ms. We can change it according to need. Also we can save the data into a file and load the data from a file after scanning. With the SHOW button we can execute the data into the intensity graph. It is useable only in FAST mode.

There are three switches for laser, lamp and photomultiplier. When the laser switch is on, the lamp switch is automatically off and unusable. Because when both switches are open the photomultiplier will be broken immediately. Also when the lamp switch is on, the laser switch is automatically off and unusable.

When the photomultiplier tube is on we can start to run this program, and stop at any time. Also we can save the data when the program is finish and load old data to the intensity graph to compare two graphs. We can also see the difference between two selected graphs. It will be showed in the ALT graph and we can also save and print it.

The Difference button is useable after we load an old data. And Save Diff. button is useable after we click Difference button.

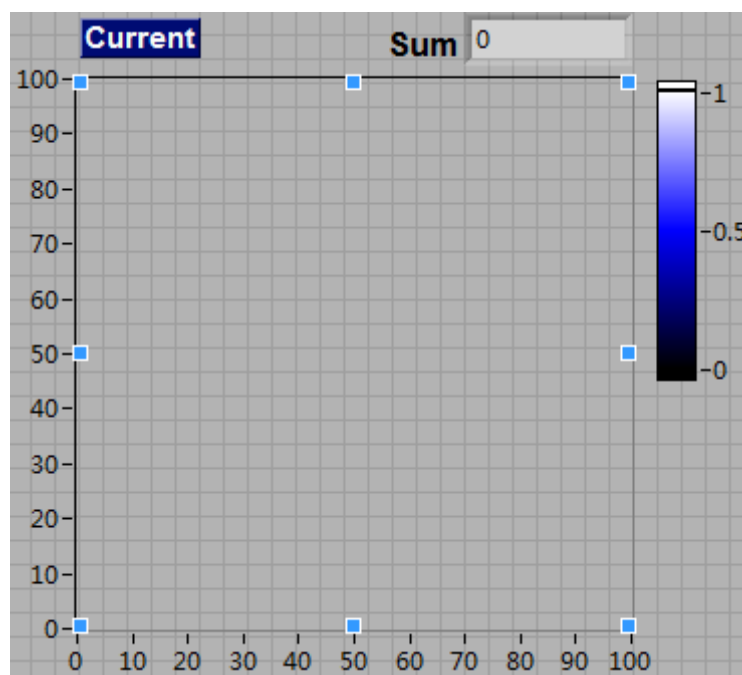


Figure 6.7 Intensity graph for current scan

The figure 6.7 shows intensity graph for current scan. We can see the data on the intensity graph and the sum of the whole data. The coordinate figure is changed automatically, from the lowest number to the highest number in the graph.

Instead of text program writing as in the Command line Interface, Labview can also write these graphically with the SubVIs (deltapositionxy.vi, wait.vi.....).

6.3.2 2D-array into intensity graph

The data of each point from the memory should be read out and displayed into a graph. We will get a 1D-array data, divided into a 2D-array for analysis.

The figure 6.8 shows example how the 2D-Array is shown in an intensity graph. If connect the array directly into the Intensity Graph, it just display the overturned graph (left diagram). Then we should dispose this array with the Functions to be shown correctly..

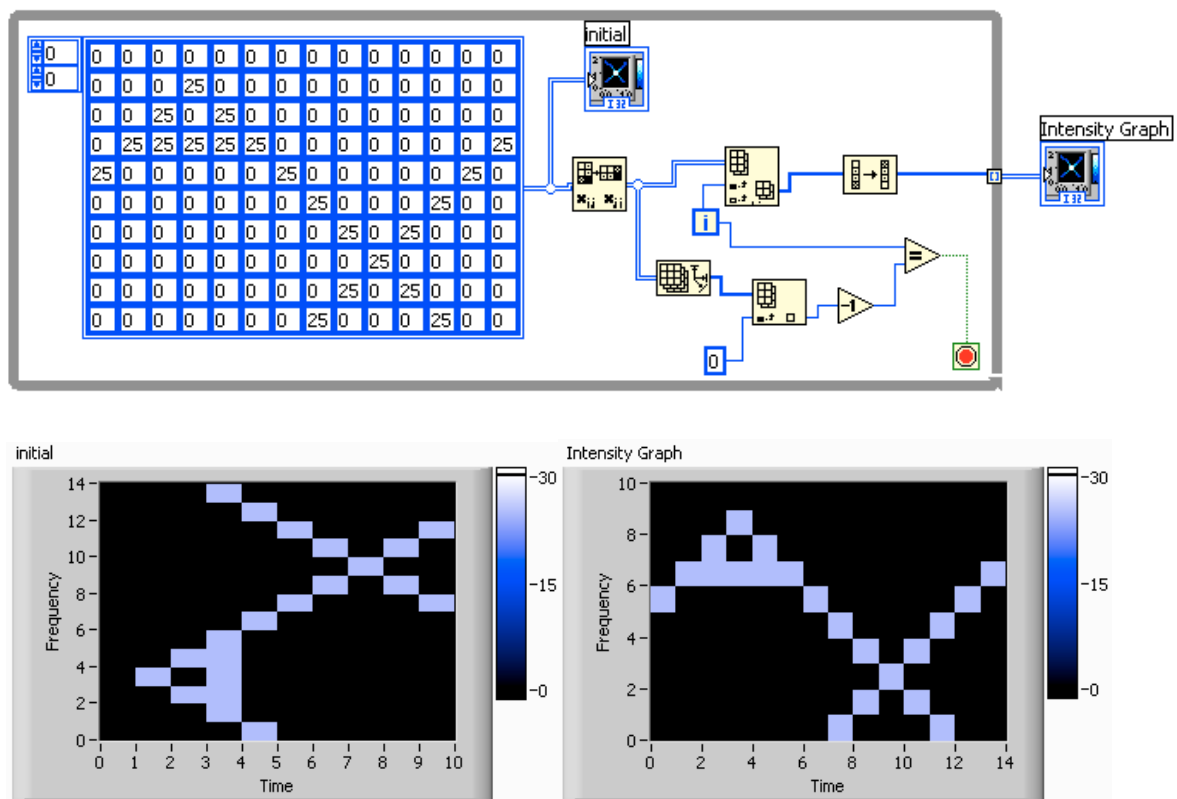


Figure 6.8 example of 2D-array into intensity graph

The figure 6.9 shows rotation of an array.

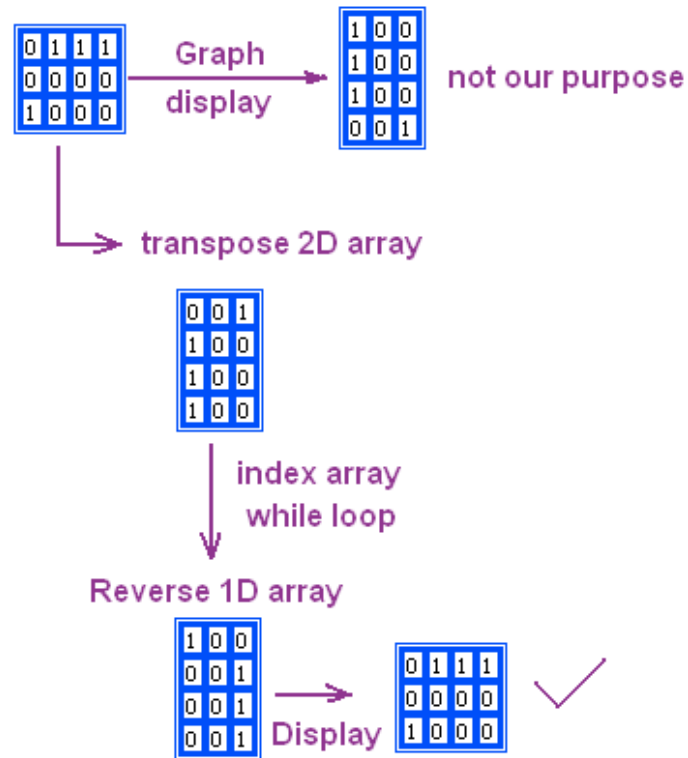


Figure 6.9 rotation of an array

6.3.3 Simulation

Use stacked sequence structure to get the 2D array from the Voltmeter with DAQ Assistant first, then analysis the array and display into an intensity graph.

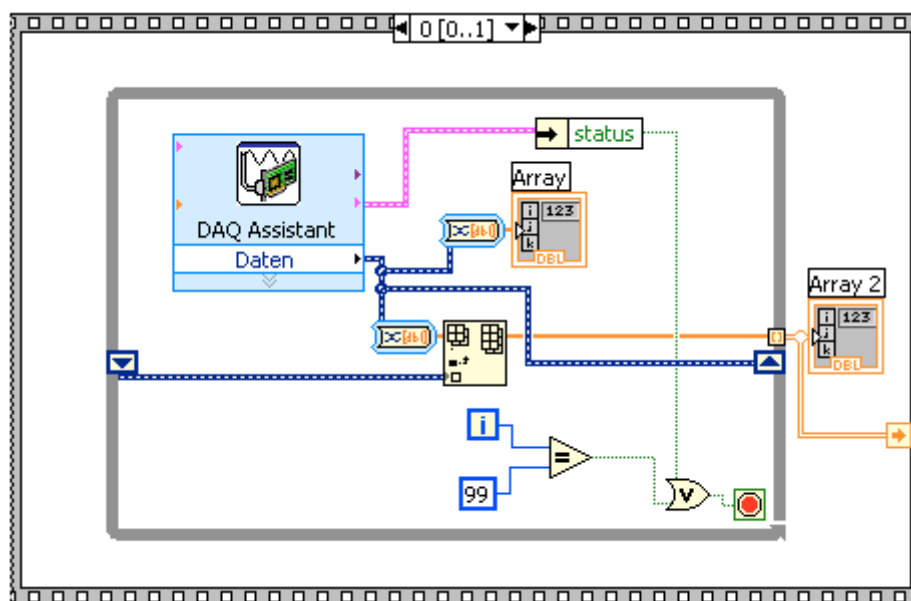


Figure 6.10 The first structure

The figure 6.10 shows the first structure in which to get values from voltmeter. The figure 6.11 shows the second structure in which to analyse the array and show in an intensity graph.

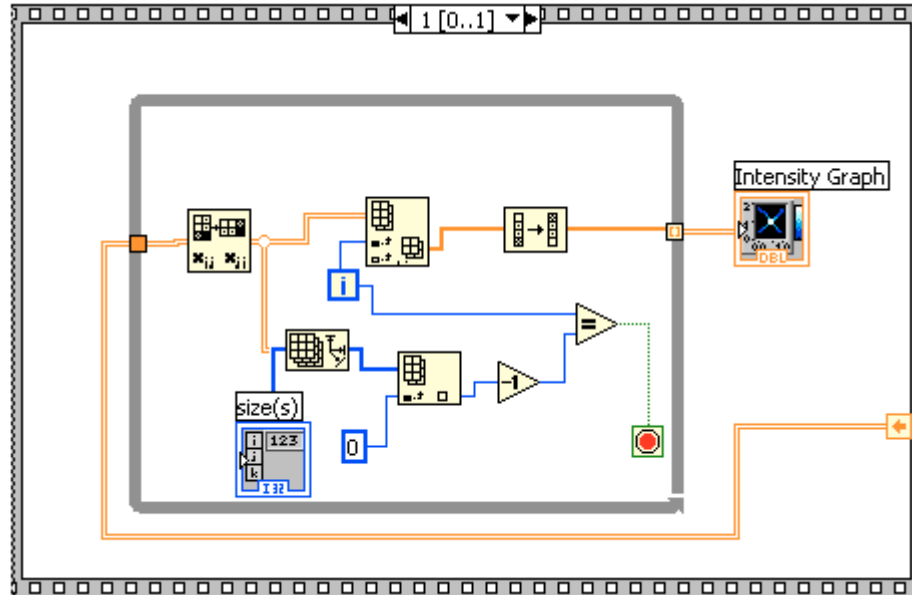


Figure 6.11 The second structure

6.3.4 Queue structure

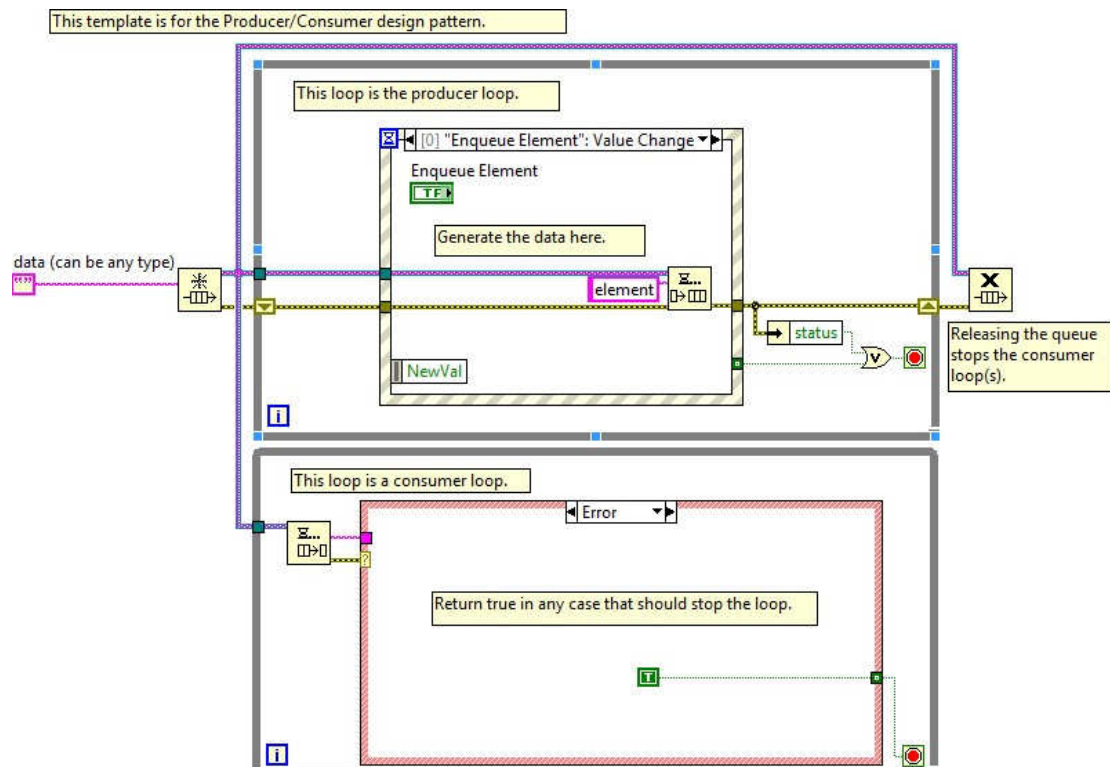


Figure 6.12 Block diagram of queue structure

The figure 6.12 shows block diagram of queue structure which is called producer/consumer design pattern. It has one produce loop and one consumer loop. In produce loop we can get measured values and put them into Enqueue function (Figure 6.13). In consumer loop we can get these values one by one through Dequeue function and put them into an array and intensity graph (Figure 6.14).

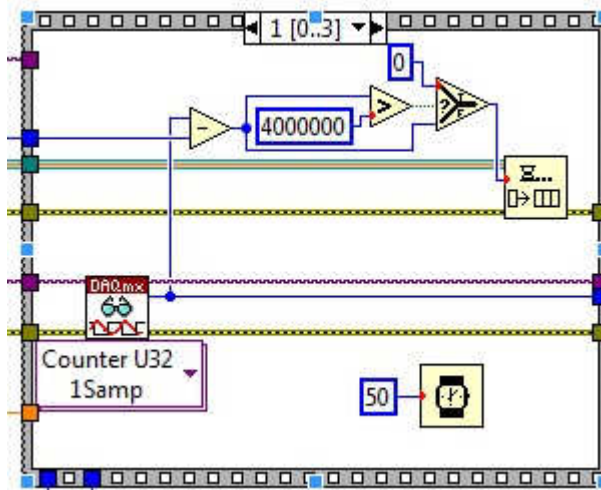


Figure 6.13 Measured values go into Enqueue function

For measuring pulse number in limited time (50ms), we use counter pinout of terminal block (CB-68LP). Then put the data into the Enqueue function.

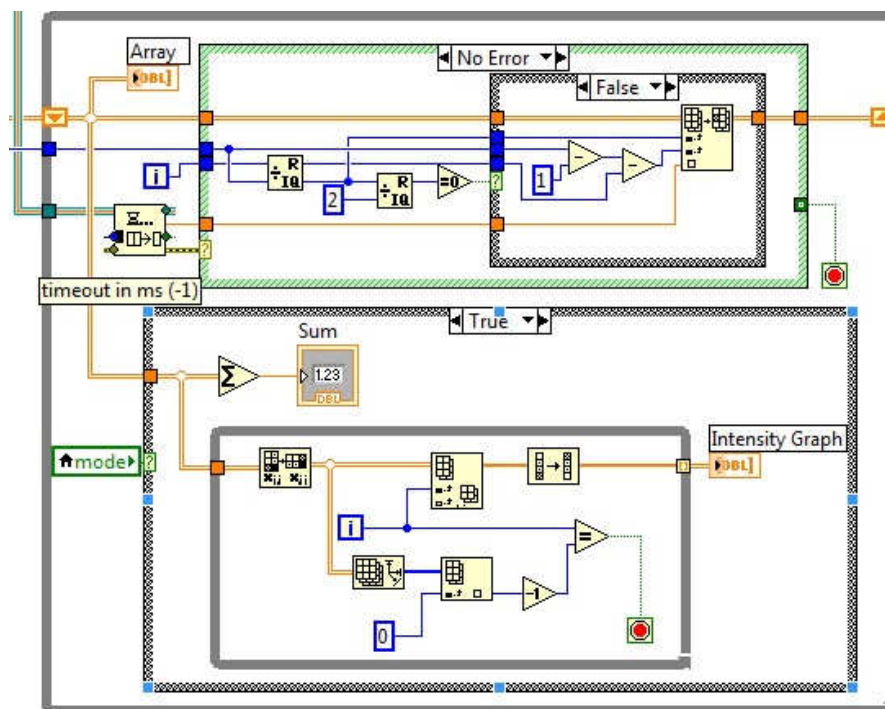


Figure 6.14 Consumer loop

The elements will be dequeued into an array and an intensity graph.

6.3.5 Array

The upper part of figure 6.14 shows how to build an array. To build an array we use a Build vi (100*100). The initial numbers are all zero. When we get values from Dequeue vi, we need replace zero to new values which we need. So we use a replace vi, and give it coordinate (column and row) and value. To determine the coordinate for each value we use Quotient&Remainder vi. According to quotient and remainder the dequeued value is put in the correct position. For example, when i is 77, it is the 78th value, because i starts from zero. 77 divided by 100 is 0 and we have 77 remainder. So this value is put to the first row the 77th column.

6.3.6 Event structure

The figure 6.15 is an event structure. It has one or more subdiagrams, or event cases, exactly one of which executes when the structure executes. The Event structure waits until an event happens, then executes the appropriate case to handle that event.

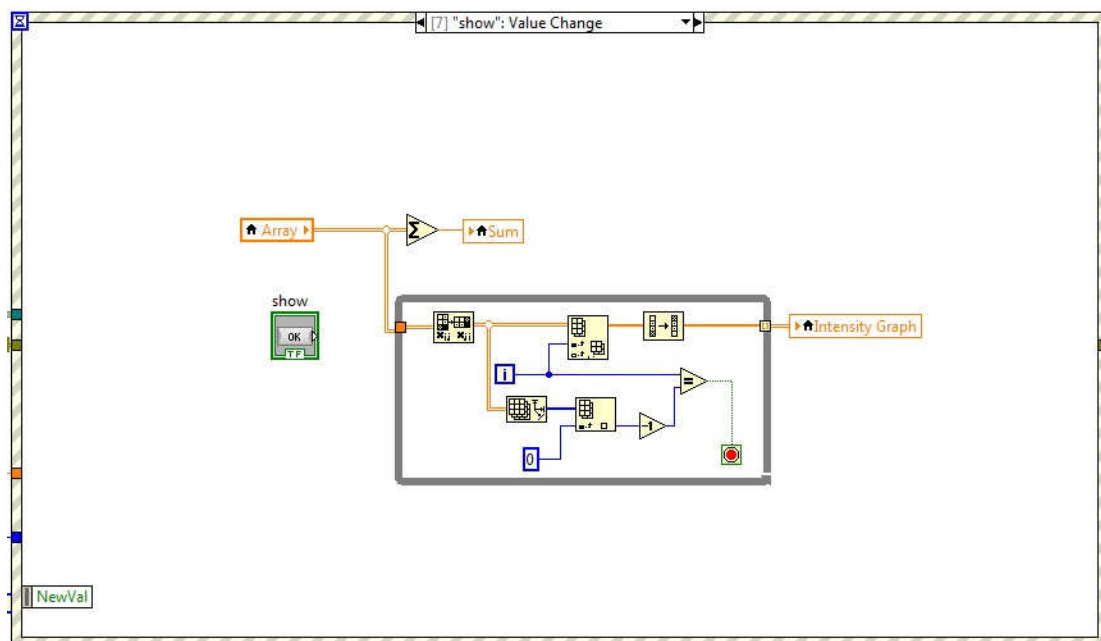


Figure 6.15 Event structure

When the value of SHOW button changed, this structure is running immediately and the data of array will be shown in the intensity graph.

Other buttons such as START, STOP, SAVE, LOAD, DIFFERENCE and PRINT work in the same way.

Conclusions

After several months' experiments, I finished this design of the program for the Laser scanner. It can be used to scan 100mm × 100mm large area or 10cm × 10cm and basically achieved the expectant request.

Although the system never used to scan any Image Plate reality, and still need to improve lots of things, but I really enjoyed the procedure and really learned a lot. Thanks all the people that helped me during these months, especially Mr. Klaus Bussmann, Mr. Peter Hiller, Prof. Dr. -Ing Christoph Helsper, Prof. Dr. Ulrich Rücker and Mr. Schmitz Bethold.

Thanks for everything!

Appendix

A. Mini SAX

Command Input Characteristics

- Differential Voltage Range: ± 3 volts differential for full scale
- Input Impedance: 5 K Ω differential

Position Output: ± 3 volts differential for full scale

Power Input

- Voltage: ± 15 to ± 24 volts DC
- Quiescent Current: +170mA, -150mA

Motor Drive Power

- Dynamic Current max.: 2.5 Amps RMS
- Peak Current: 10.0 Amps

Note: U20/U21 mounting screws should be tightened to a torque of 16 in-lb (1.8 N-M).

Control I/O Characteristics

- Servo Ready: Open Drain, Active Low (50 mA max.)
 - Servo Enable: TTL/CMOS Compatible, Active Low
 - Temp OK*: Open Drain, Active Low (50 mA max.)
- * Part of optional Temperature Controller Module

Protection

- Fully Fused: Motor Output, Automatic Gain Control, and Thermal Controller
- Automatic Shutoff: Over-position, Supply Undervoltage, Position Detector Inactive

Temperature Range: 0°C to 50°C Operating

Size W x L x H (without mounting bracket): $2\frac{1}{8}$ " x $3\frac{3}{8}$ " x $1\frac{1}{4}$ "

(54.5mm x 86.5mm x 31.35mm)

Weight: 66 grams (Includes all optional modules, without mounting bracket)

B. DAQ-Card 6024E

General

Product Name PCI-6024E

Product Family Multifunction Data Acquisition

Form Factor PCI

Part Number 777743-01

Operating System/Target Real-Time , Linux , Mac OS , Windows

LabVIEW RT Support Yes

DAQ Product Family E Series

RoHS Compliant No

Analog Input

Channels 16 , 8

Single-Ended Channels 16

Differential Channels 8

Resolution 12 bits

Sample Rate 200 kS/s

Max Voltage 10 V

Maximum Voltage Range -10 V , 10 V

Maximum Voltage Range Accuracy 16.504 mV

Minimum Voltage Range -50 mV , 50 mV

Minimum Voltage Range Accuracy 0.106 mV

Number of Ranges 4

Simultaneous Sampling No

On-Board Memory 512 samples

Analog Output

Channels 2

Resolution 12 bits

Max Voltage 10 V

Maximum Voltage Range -10 V , 10 V

Maximum Voltage Range Accuracy 8.127 mV

Minimum Voltage Range -10 V , 10 V

Minimum Voltage Range Accuracy 8.127 mV

Update Rate 10 kS/s

Current Drive Single 5 mA

Digital I/O

Bidirectional Channels 8

Input-Only Channels 0

Output-Only Channels 0

Number of Channels 8

Timing Software
Logic Levels TTL
Input Current Flow Sinking , Sourcing
Output Current Flow Sinking , Sourcing
Programmable Input Filters No
Supports Programmable Power-Up States? No
Current Drive Single 24 mA
Current Drive All 192 mA
Watchdog Timer No
Supports Handshaking I/O? No
Supports Pattern I/O? No
Maximum Input Range 5 V
Maximum Output Range 5 V

Counter/Timers

Counters 2
Number of DMA Channels 1
Buffered Operations Yes
Debouncing/Glitch Removal No
GPS Synchronization No
Maximum Range 0 V , 5 V
Max Source Frequency 20 MHz
Minimum Input Pulse Width 10 ns
Pulse Generation Yes
Resolution 24 bits
Timebase Stability 100 ppm
Logic Levels TTL

Physical Specifications

Length 17.5 cm
Width 10.7 cm
I/O Connector 68-pin male SCSI-II type

Timing/Triggering/Synchronization

Triggering Digital
Synchronization Bus (RTSI) Yes

C. Relays

1. ABB Relay

General Information

Extended Product Type: R600 RB121 5vdc

Product ID: 1SNA645034R2300

EAN: 3472596450342

Catalog Description: RB121 5vdc

Long Description: Screw relay RB121 5vdc : 5vdc input / 1SPDT 10 mA up to 6A with led

Dimensions

Product Net Width: 6 mm

Product Net Height: 70 mm

Product Net Depth: 67.5 mm

Product Net Weight: 0.02 kg

Environmental

Ambient Air Temperature:

Operation -20 ... 70 °C

Storage -40 ... 80 °C

Certificates and Declarations (Document Number)

Declaration of Conformity - CE: 1SND225042C1000

LR Certificate: LRS_0620042

Additional Information

IIT Publishing Status: Level 0 - Information enabled

Invoice Description: RB121 5vdc

Minimum switching capacity [V/mA]: 12 / 10 volt per milliamp

Number of Auxiliary Contacts CO (SPDT): 1

Output Current Maximum (I_{out}): 6 A

Output Voltage (U_{out}): 250 V AC

Product Main Type: R600

Product Name: Relay module

Rated Control Supply Voltage (U_s): 5 V DC

Recommended Screw Driver: 3.5 mm

Standards: CEI 947-7-1 / CEI 947-1 / CEI 1131-2 (in relevant parts) / CEI 60664-1 /

CEM : IRC 1000-4-2. 3. 4. 5. 6.

Wire Stripping Length: 9 mm

2. PhoenixContact Relay

Input data

Nominal input voltage U_N	5 V DC
Input voltage range in reference to U_N	0.8 ... 1.2
Switching threshold "0" signal in reference to U_N	≤ 0.4
Switching threshold "1" signal in reference to U_N	≥ 0.8
Typical input current at U_N	5 mA
Typical response time	0.8 ms
Typical turn-off time	1.5 ms
Operating voltage display	Yellow LED
Type of protection	Protection against polarity reversal Surge protection
Protective circuit/component	Polarity protection diode Varistor
Transmission frequency	50 Hz

Output data

Output nominal voltage range	12 V DC ... 300 V DC (Partition plate PLC-ATP must be installed for voltages larger than 250 V (L1, L2, L3) between identical terminal points in adjacent modules. Potential bridging is then carried out with FBST 8-PLC... or ...FBST 500...)
Limiting continuous current	1 A (see derating curve)
Voltage drop at max. limiting continuous current	< 500 mV
Type of protection	Protection against polarity reversal Surge protection
Protective circuit/component	Polarity protection diode Varistor

Connection data

Connection method	Screw connection
Stripping length	8 mm
Screw thread	M3
Conductor cross section solid min.	0.14 mm ²
Conductor cross section solid max.	2.5 mm ²
Conductor cross section stranded min.	0.14 mm ²

Conductor cross section stranded max.	2.5 mm ²
Conductor cross section AWG/kcmil min.	26
Conductor cross section AWG/kcmil max.	14

General data

Width	6.2 mm
Height	80 mm
Depth	86 mm
Ambient temperature (operation)	-25 °C ... 60 °C
Ambient temperature (storage/transport)	-40 °C ... 85 °C
Mounting position	Any
Assembly instructions	In rows with zero spacing
Operating mode	100% operating factor
Inflammability class acc. to UL 94	V0
Name	Standards/regulations
Standards/regulations	IEC 60664
	EN 50178
	IEC 62103
Rated surge voltage / insulation	4 kV / basic insulation
Rated insulation voltage	300 V
Pollution degree	2
Surge voltage category	III

D. Command Reference

?FreeFlashSpace: Returns byte count of available flash memory.

?FreeRAMSpace: Returns byte count of available SRAM.

?ID: Return system revision information.

?OpticalCal

?Position: Return the current position on the given axis.

?Status: Returns error information and clears error state.

?Sync

?Temp

?TempOK

AbortPgm: Halts the currently running program and disables servos.

ComConfig: Configure RS-232 serial port parameters for communication.

CreateFlashPgm: The action of Create Flash Program is to initiate the storage mechanism in the Scan Controller so that a program may be saved to non-volatile memory on-board the Scan Controller.

CreatePgm: Store a Scan Controller program in volatile memory on-board the Scan Controller.

DelayedLaserGate

DelayedSetFPS

DelayedSetOutputSignal

DelayedSetSync

DelayedUnSetSync

DeltaPosition: Set the position of the current axis relative to the currentposition.

DeltaPositionXY: Set the vector position relative to the current position.

DeltaSlew: Move smoothly on the current axis relative to the currentposition.

DeltaSlewXY: Move smoothly relative to the current vectorposition.

DeltaTweakAxis: Apply gain and offset deltas to subsequent raster operations.

DeltaTweakAxisXY: Apply gain and offset deltas to subsequent vector operations.

End: Marks the end of a Scan Controller program.

ExecutePgm: Commence the execution of the named program.

ExecuteRasterPgm

ExecBinPgm

ExecSerialNumber

ExitPgm: Use ExitPgm to terminate programs by having them fall through repeat and waitsync [1-4] statements.

FlipExchangeAxis: Use FlipExchangeAxis to reverse the sense of one or both axis and to interchange the command stream between X and Y.

Ifexecutepgm

Ifexecuterasterpgm

Iftempokexecutepgm

Iftempokexecuterasterpgm

LaserModeSetup

Nrepeat

PackMemory

Position: Set the absolute position of the current axis.

PositionXY: Set the absolute vector position.

Raster: Declare the target axis for subsequent single axis (raster) commands and place the Scan Controller in raster mode.

ReleasePgm

Repeat: The Repeat command will cause the Scan Controller program flow to return to the first instruction in the program where execution is repeated.

SaveConfigInFlash

SerialNumberSetup

SetAnalogOutput

SetConfigVar

SetFPS

SetGSS

SetLaserPower

SetMOFGains

SetMOFMode

SetMOFShift

SetOutputSignal

SetPWM

SetSetSyncDelay

SetSync

SetTicklePulses

SetUnsetSyncDelay

SetXPRGain

SetXPROffset

SetYPRGain

SetYPROffset

Slew: Move smoothly to the given absolute position on the current axis in the specified number of tick counts.

SlewXY: Move smoothly to the given absolute vector position in the specified number of tick counts.

TransformAxis: Apply rotation or skew transformation to vector motion commands.

TweakAxis: Apply gain and offset to subsequent axis operations.

TweakAxisXY: Apply gain and offset to subsequent vector operations.

UnSetSync

Vector: Place the Scan Controller in vector mode.

Wait: Pause execution for the given number of tick counts.

WaitPosition: Pause Scan Controller program execution until the commanded position for the current axis is reached.

WaitPositionXY: Pause Scan Controller program execution until the commanded position is reached.

WaitSync

References

GSI LUMONICS SC2000 COMMAND REFERENCE

GSI LUMONICS SC2000 SUPPORT PROGRAMS MANUAL

GSI LUMONICS SC2000 USER MANUAL

GSI LUMONICS SC2000 QUICK START GUIDE

VM500 VM1000 & VM1500 USER'S MANUAL

MINI SAX USER MANUAL

DAQ 6023E/6024E/6025E USER MANUAL

[HTTP://WWW.NI.COM/](http://www.ni.com/)

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