

# A Technical Report on Design Process and Implementation of a LabVIEW based GUI with Associated Electronics for Operating and Monitoring Vacuum Components and Sensors of a Synchrotron Beam Line

Avijit Das

**Abstract** — This document reports on technical developments of hardware and software for data acquisition from different sensors, measuring gauges, remote operation of several pneumatic high vacuum components and vacuum gate valves of a Grazing Incidence X-ray Scattering (GIXS) beamline at Indus2 synchrotron radiation source in India. Techniques of implementing the software-hardware integration between LabVIEW graphical programme based user interface (GUI) and custom-made electronic actuating circuit prepared in-house are discussed in detail. An indirect method of reading the output current from twelve sensors at a time without using RS-485 communication system is one of the worth mentioning aspect of this developmental work. The design concepts utilized here are interesting in challenging and critical situation of instrumentation even though the techniques adopted may appear conventional at first glance.

**Keywords** — Synchrotron beamline, DAQ card, LabVIEW, Virtual Instrument, Data acquisition, Microcontroller, Flow sensor

## 1 INTRODUCTION

The only synchrotron radiation sources in India were developed by Raja Ramanna Centre for Advanced Technology (RRCAT) called "Indus". Indus-1 is a 450 MeV electron storage ring, whereas Indus-2 is a booster cum storage ring that can accelerate electrons from injection energy of 550 MeV to 2.5 GeV. Among the fifteen commissioned beamlines till the year 2021, the thirteenth number of beamline is Grazing Incidence X-ray Scattering (GIXS) Beamline that has been designed, installed and maintained by Surface Physics and Material Science Division of Saha Institute of Nuclear Physics, Kolkata and funded by Department of Atomic Energy, Government of India. The beamline has been planned to be used for grazing incidence x-ray scattering studies of surfaces and interfaces in ambient, low and high temperature.

This report is an elaborate documentation about control of few beamline components, vacuum gate valves and monitoring of chilled water flow parameters as well as vacuum level at different segments of approximately 15 meter long (exposed outside the storage ring concrete wall) high vacuum pipe line of around 100 mm inside diameter. The plan for this customized control architecture was made at a time when our research group was going to design and implement an x-ray

beamline at Indus-II synchrotron source. Most of our scientific group members had prolonged experience on using synchrotron beam line facilities worldwide.

This GIXS beamline is the thirteenth number of beamline within Indus-II Synchrotron Centre. Oxford Danfysik, UK (currently known as FMB-Oxford) was the supplier of most of the major and vital beam guiding and control instruments and those were controlled by their own control system. But, all the three monochromatic fluorescent screens, commonly known as Beam Position Monitors (BPM) and an experimental hutch Safety Shutter, though supplied by Oxford Danfysik, were left free to be handled by the users themselves.

Along with these four Oxford Danfysik instruments there were five pneumatic vacuum gate valves (manufacturer : VAT VAKUUMVENTILE AG, Switzerland) in our beamline. Initially it was planned to operate these valves also from the computer Graphical User Interface (GUI) screen. There were three pumping stations comprised of a Turbo-molecular pump, a rotary vane backing pump and a cold cathode gauge with its electronic controller. These entire gauge controllers had to connect to the control PC by RS232 communication line to help the users to read current pressure in all three beamline segments separated from each other by Beryllium windows.

---

*Avijit Das is currently working in the position of Scientific Officer in Saha Institute of Nuclear Physics, Kolkata, India.  
E-mail : avijit.das@saha.ac.in*

## 2. TECHNICAL DISCUSSION ABOUT CONTROL SOFTWARE AND RELATED HARDWARE

To build a desktop PC graphical user interface application for control and data acquisition purpose, we chose LabVIEW software package developed by National Instruments, USA. LabVIEW is a graphical programming environment for monitoring, control and measurement purpose, widely used by engineers and scientists to create their interactive software application. We had purchased NI LabVIEW version 7.1 full professional package to use it for this project. In the NI LabVIEW graphical development environment, it is easy to develop data acquisition applications using drag-and-drop graphical icons instead of writing many lines of text based code in traditional programming languages.

One National Instruments (NI) 6251 DAQmx card (High Speed M-Series Multifunction Data Acquisition Board) compatible for PCI slots was purchased for this project. This High-Speed M-Series Multifunction DAQ card had 68 pins at its terminal which comprises of sixteen analogue inputs, two analogue outputs and 24 digital input/output pins. One eight-serial-port Specialix IO8+ PCI card (manufacturer : Perle Systems Inc, USA) was also purchased to interface all serial devices like, vacuum gauge controllers using RS-232 communication method.

The control PC that we purchased locally had two PCI slots on its motherboard. Among these two, I had used the first one for NI 6251 DAQmx card and another one for a multi-serial port card. NI-DAQmx driver software was needed for operation of the DAQ card that directly programs the registers of the DAQ hardware, managing its operation and its integration with the computer resources, such as processor interrupts, DMA and memory. It hides the low-level complicated details of hardware programming, providing the user with an easy-to-understand stand-alone application.

DAQ Assistant is an easy-to-use graphical interface for configuring measurement tasks in LabVIEW. Using the DAQ Assistant, it is possible to configure a virtual channel and measurement task for any DAQ applications. I chose DAQ Assistant Express VI from appropriate location on Functions palette and dropped on the block diagram. DAQmx Express VI was configured by selecting line inputs and line outputs of the PCI card 8 bit digital ports P0 and P2.

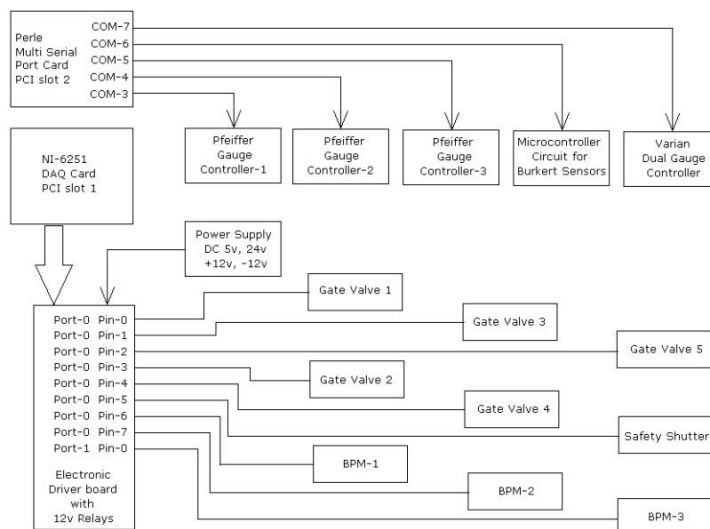


Fig.1. Over all connection diagram of PC interfaced control and monitoring system used for more than ten years up to 2019.

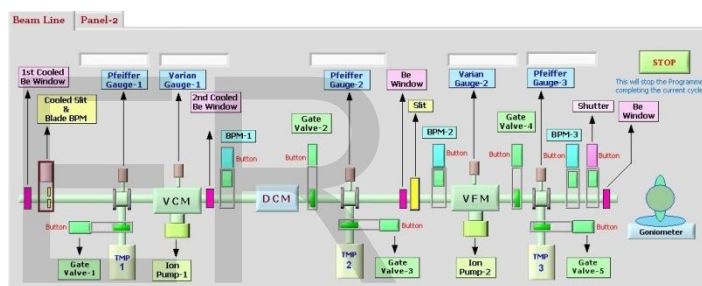


Fig. 2. Screenshot of the main user interface screen developed with LabVIEW 7.1 (2010)

Within LabVIEW block diagram, a main *While Loop* was created and within this endless loop, another *Flat Sequence Structure* had been used to communicate the serial devices one after another with few hundreds of milliseconds of delay, like Pfeiffer Single Channel Gauge controller TPG 261, Varian dual gauge controller and a self-made Burkert sensor current (4-20 mA) output read circuit. Perle multi serial port Specialix IO8+ PCI card was used to communicate with all these devices. It had eight RJ-12 terminal sockets on its back-plane exposed to outside the PC cabinet. Eight numbers of female DCE cables were supplied along with this card with RJ-12 connector at one end and 25 pin female type D-connector at its other end. Connection details have been shown in Table 1.

Table 1

| RJ-12 socket on the cable supplied | 25 pin D connector of the cable | 9 pin D connector on Pfeiffer gauge controller |
|------------------------------------|---------------------------------|--|
| pin - 2                            | pin - 2                         | pin -3 (Tx)                                    |
| pin - 5                            | pin - 3                         | pin - 2(Rx)                                    |
| pin - 4                            | pin - 7                         | pin - 5 (Gnd)                                  |

Separate sub programme files were prepared, called *Sub VI* in LabVIEW to handle communication through each serial port as described in Table 2. These *Sub VIs* were called one by one from this sequential loop and built an acquisition cycle that kept on reading the data sent from the devices attached, until the STOP button on the *Front Panel* was pressed (shown in Fig. 3).

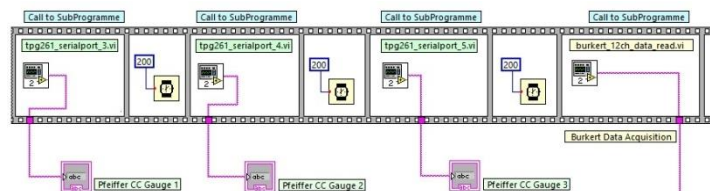


Fig. 3. Sequential call of Sub-VIs in cyclic order within the main *While Loop*.

Long braided RS-232 cables (3-wire – Rx, Tx and Gnd) were prepared to connect the control PC to each of the Pfeiffer gauge controllers placed in three different positions like ultra high vacuum (UHV) region near Vertical Collimating Mirror (VCM), high vacuum(HV) region near DCM and HV region near Vertical Focusing Mirror (VFM). All these regions were separated from each other by Beryllium Windows supplied by Oxford Danfysik. The longest cable was around 20 meters long while the shortest one was around 10 meters. Varian dual gauge controller was interfaced from COM-7 which reads pressure from two ion gauges, one attached on VCM chamber and another one on VFM.

Table 2

| Port Numbers of SpecialixIO8+ card | Attached instruments  |
|------------------------------------|---|
| COM-3                              | Pfeiffer single gauge controller-1 of VCM segment               |
| COM-4                              | Pfeiffer single gauge controller-2 of DCM segment               |
| COM-5                              | Pfeiffer single gauge controller-3 of VFM segment               |
| COM-6                              | Microcontroller based self-designed circuit for Burkert sensors |
| COM-7                              | Varian dual gauge controller                                    |
| COM-8 to 10                        | unused  |

For serial data communication over RS-232 line I had used NI-VISA (*Virtual Instrument Software Architecture*) API (*Application Programming Interface*) that has bus-independent functions for most of its I/O functionality. It has drag and drop virtual instrument icons available on block diagram Functions Palette to read, write, and configure a programming interface to control Ethernet, GPIB, Serial, USB and VXI instruments in NI application development environment.

## 2.1 Serial Communication with Pfeiffer Compact Gauge Controller

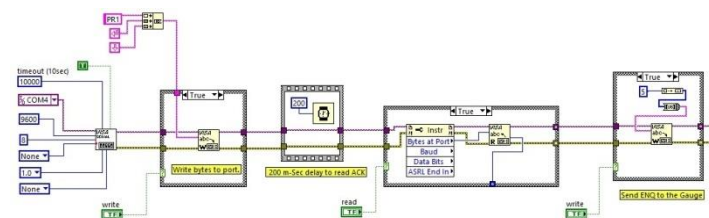


Fig. 4. Part of the LabVIEW Block diagram for RS-232 communication with TPG 261 Gauge controller

Pfeiffer TPG 261 is single channel measurement and control unit for compact gauges. We had three such cold cathode gauges attached on beam pipe line mentioned in Table 2. All these devices has 9 pin D-sub connector RS-232 ports at rear panel. Three wire serial cable (crossed) were used for signal transmission. The data transmission at 9600 baud rate was bi-directional and data format was comprised of 1 start bit, 8 data bits, 1 stop bit with no parity bit. Enquiry message were transmitted to the TPG 261 as ASCII strings in the form of mnemonics comprised of three ASCII characters 'PR1' followed by carriage return and line feed. TPG 261 acknowledges by sending <ACK><CR><LF>. Host PC again sends a number decimal 5 (or 0x05) that is equivalent to <ENQ> command (described in the manual in Section 1.2.1) and receives a string that denotes the measured pressure displayed in a text box on the *Front Panel*. This text box indicator was linked with the *Connector Pan* that conveyed the data to the main programme when the sub programmed was called.

## 2.2 Serial Communication with Varian Multi-Gauge Controller

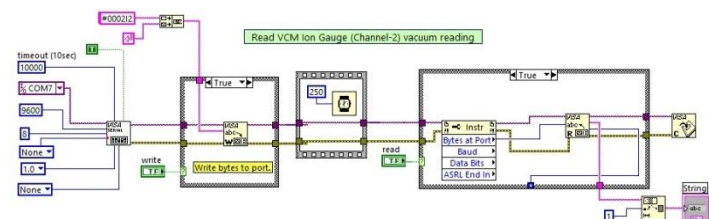


Fig. 5. Block diagram for RS-232 communication with Varian dual-gauge controller

It monitors vacuum gauge readings from two cold-cathode ionization gauges - one attached on VCM chamber and another on VFM. It was connected with 3-wire RS-232 cable on Com Port-7 of the multi-serial port PCI card. Two separate LabVIEW sub-programmes were created (one shown

in Fig. 5) for receiving gauge reading from two different cards inside a common controller cabinet. 1 start bit, 8 data bits, 1 stop bit with no parity bit and 9600 baud rate was used as communication data format. The command format was as following,

# {address} {command} {data} {carriage return}

Command set to read pressure was #aa02cnt where,

- aa hexadecimal bus address that is 00 in case of RS-232 communication method.
- c channel type that is 'T' for cold cathode gauge
- n channel number that is 1 for the gauge on VFM and 2 for the gauge on VCM
- t denotes terminator character that is Carriage Return.

Enquiry command #0002I1 was sent to read back the pressure from VFM chamber and #0002I2 sent to read the pressure from VCM. In this case also gauge readings were displayed on Front Panel text boxes and transferred data to the main programme via the *Connector Pan*.

### 2.3 Use of DAQ Card ports and individual pins

Apart from the main data acquisition *While Loop*, another *While Loop* was created in parallel to operate the 6251 DAQ card port pins. The Front Panel clickable buttons, those were of Boolean data type, used for actuating the shutter, BPM and vacuum gate valves in the block diagram of LabVIEW GUI when toggled with mouse click, used to generate a logic 1 or 0. Eight such *Front Panel* buttons were connected to a *Build Array* element inputs in *Block Diagram* and the output of the *Build Array* element, that was an 8 bit data, was fed to the data input of the DAQ Assistant block. This DAQ Assistant block did set the physical Port-0 pin values according to the data byte appeared on *Build Array* element output (as shown in Fig. 6) and in turn actuates 12v OMRON relays (shown in Table 3).

Fig. 6. Part of the *Block Diagram* screenshot of graphically represented source code for toggling action of *Front Panel* clickable buttons as shown on Fig. 2.

NI SCB-68 E-series quick connector shielded I/O termination box had been used to screw up wires to link the PCI card with the external components inside the relay driver cabinet. It had an additional one meter long shielded cable to attach the screw terminals with the PCI card.

The NI-DAQmx card had three 8 bit digital input/output ports P0, P1 and P2. Eight pins of Port-0 and Port-1 had been used for switching 12v relays inside the self-made electronic driver box. All pins of Port-0 of NI-6251 card were open collector, hence external 4.7K resistors were necessary to connect each pins to 5v terminal for using this port. The port output current of the card is limited and was not sufficient to drive a 12v relay. Hence, to increase this relay coil actuating current, few Darlington-pair driver ICs (ULN2003) had been added in between port pins and relay coils.

Table 3. Port-0 and Port-1 pin description and action.

| Port pin number     | Relay Number  | Pneumatic components to operate                   |
|---------------------|---------------|---|
| Port-0, Pin No. 0   | Relay-1       | Gate Valve 1, operated with 24v DC                |
| Port-0, Pin No. 1   | Relay-2       | Gate Valve 3, operated with 220v AC               |
| Port-0, Pin No. 2   | Relay-3       | Gate Valve 5, operated with 220v AC               |
| Port-0, Pin No. 3   | Relay-4       | Gate Valve 2, operated with 24v DC                |
| Port-0, Pin No. 4   | Relay-5       | Gate Valve 4, operated with 24v DC                |
| Port-0, Pin No. 5   | Relay-6       | Safety Shutter, operated with 24v DC              |
| Port-0, Pin No. 6   | Relay-7       | BPM-1, operated with 24v DC                       |
| Port-0, Pin No. 7   | Relay-8       | BPM-2, operated with 24v DC                       |
| Port-1, Pin No. 0   | Relay-9       | BPM-3, operated with 24v DC                       |
| Port-1, Pin No. 1-7 | No connection | All were unused and left free for any future use. |

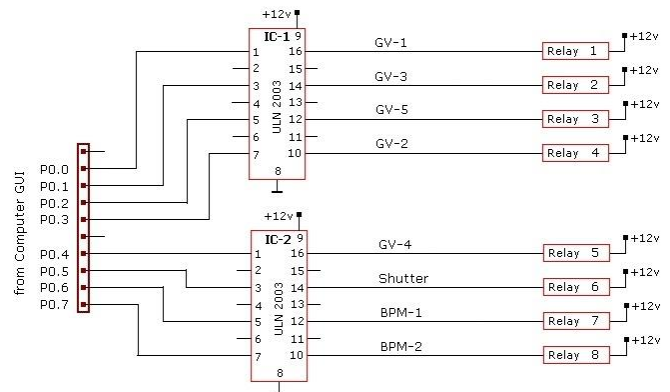
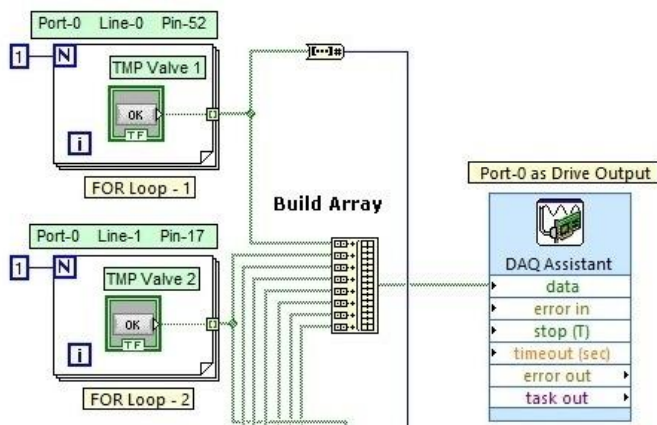


Fig. 7. Schematic diagram of NI-6251 Port-0 physical connection with relay driver circuit.

Port-2 was used to read the position status from safety

shutter and fluorescent screens (also called as Beam Position Monitor or BPM). Each BPM had 12 way Trim Trio connectors on its metal housing where five connector pins had been utilized. 24v supply was essential to actuate the Bosch solenoid operated pneumatic valve to drive the screen inside the vacuum chamber onto beam path or release it out. Positive 5v supply had been given to one pair of end-of-travel limit switches that gave a physical indication about the position of the movable part inside the UHV vessel.

Table 4. Status feedback input lines (LED indications)

| Port pin details  | Component Status              | LED on Controller Panel | Return Boolean type |       |
|-------------------|-------------------------------|-------------------------|---------------------|-------|
|                   |                               |                         | True                | False |
| Port-2, Pin No. 0 | Shutter Closed                | Green                   | ON                  | OFF   |
| Port-2, Pin No. 1 | Shutter Open                  | Red                     | ON                  | OFF   |
| Port-2, Pin No. 2 | Screen-1 out of the beam path | Blue                    | ON                  | OFF   |
| Port-2, Pin No. 3 | Screen-1 inside the beam path | Red                     | ON                  | OFF   |
| Port-2, Pin No. 4 | Screen-2 out of the beam path | Blue                    | ON                  | OFF   |
| Port-2, Pin No. 5 | Screen-2 inside the beam path | Red                     | ON                  | OFF   |
| Port-2, Pin No. 6 | Screen-3 out of the beam path | Blue                    | ON                  | OFF   |
| Port-2, Pin No. 7 | Screen-3 inside the beam path | Red                     | ON                  | OFF   |

In LabVIEW application, another DAQ Assistant VI was created (shown in Fig. 8) for 6251 DAQmx card Port-2 to receive position feedback signals from safety shutter and three BPMs. Input byte received from Port-2 was segregated by an Index Array VI to separate out each bits to switch eight front panel LEDs on or off as well as hardware controller cabinet LEDs (shown in Fig. 9) as quick visual indication of actual position status of these two types of beamline components.

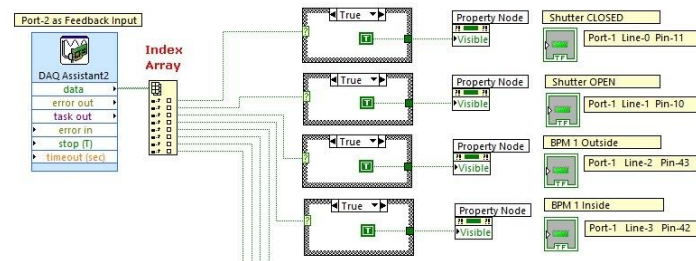


Fig. 8. Part of the Block Diagram screenshot for reading status feedback data bits from NI-6251PCI card Port-2 pins and display as LED indicators on Front Panel.

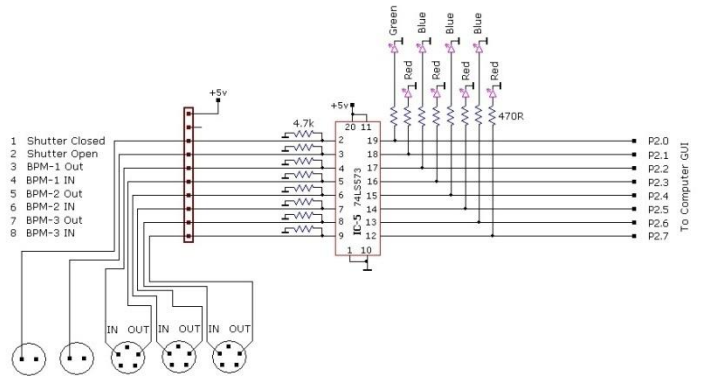


Fig. 9. Connection diagram of beamline component position status feedback lines. Those operate physical LED components on controller cabinet front panel, as well as virtual LED indicators on computer graphical screen. All the round shape connectors were 2 and 5 pin Aviation Plug sockets.

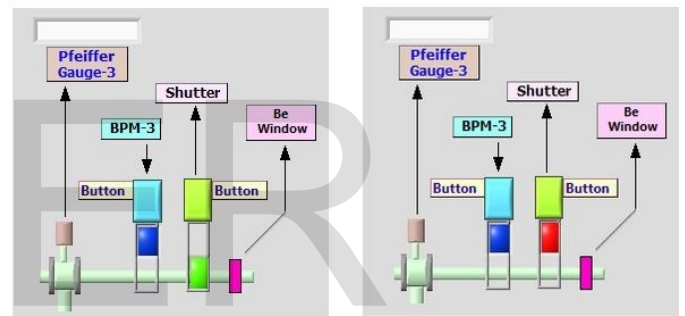


Fig. 10. Screenshots to show Safety Shutter position in closed condition (Green LED indication) on the left side and in opened condition (RED LED indication) on the right.

Vacuum gate valve positions were not read through DAQ card port pins to keep few digital lines free for any future use. The positions of gate valves were indicated on the GUI as software simulation. Gate valve positions were also Boolean indicators directly connected to the valve operating buttons. But finally it was decided to keep the vacuum gate valves free to operate manually by applying required voltage (either 24v DC or 230v AC) with common electrical switches. Hence, the valve operating digital lines (Port-0, Pin No. 0 to 4) are still now not in use.

### 3. NEW IDEA IMPLEMENTED TO MONITOR CHILLED WATER FLOW RATE AND PRESSURE

Some of the major instruments supplied by Oxford-Danfysik like Vertical Collimated Mirror (VCM), Double Crys-

tal Monochromator, White Beam Slits, first Beam Position Monitor and two Beryllium windows – all these parts had integrated chilled water circulation pipe lines, as these components have to handle the high energy white synchrotron beam coming out of the synchrotron ring wall port. Non-aggressive de-ionized chilled water supply was mandatory at a recommended flow rate, within a certain pressure limit, mentioned by the manufacturer in their product manual.

We had purchased few paddle type water flow sensors and pressure transmitters of different rates from Burkert Contromatic Pvt. Ltd. (manufactured in Germany) in the year 2008. Pressure Transmitters (Model type-8314) of two different ranges 0-6 bar and 0-10 bar were purchased. And Flow sensors (Model-8012) of three types 0.5-3 L/min, 0.8-6 L/min and 3-18 L/min were purchased. All these sensors used to produce 4-20 mA current output that varies linearly with the flow or pressure of the liquid within the pipe line.

We had also purchased required numbers of electronics monitors with seven segment LED display to visually monitor the amount of water flow in litres per minute along with the pressure inside the pipe lines. All these monitors had RS-485 modules placed inside and my plan was to read the variables on the PC GUI to keep constant watch on the water flow parameters from the user's room. The vendor insisted to include a dedicated software package specially for interfacing these instruments. But, as we desired to integrate all kind of devices to a single monitoring GUI in our PC - we didn't add it in our purchase list. Unfortunately, the command sets supplied by the local vendors did not work. I had tried to verify the interfacing method in various languages, like C, Java and LabVIEW - but all my efforts went in vain.

Finally, to read the flow rate and pressure from these twelve numbers of sensors, I adopted a novel plan to design an electronic circuit that would pass through the output current (varies from 4 to 20 mA) from all the 12 number of sensors those were also entering the display devices. An AT89S52 8-bit Microcontroller (McU) was used as a main control chip for this circuit. Fig-11 will illustrate the modified connection diagram to achieve this purpose.

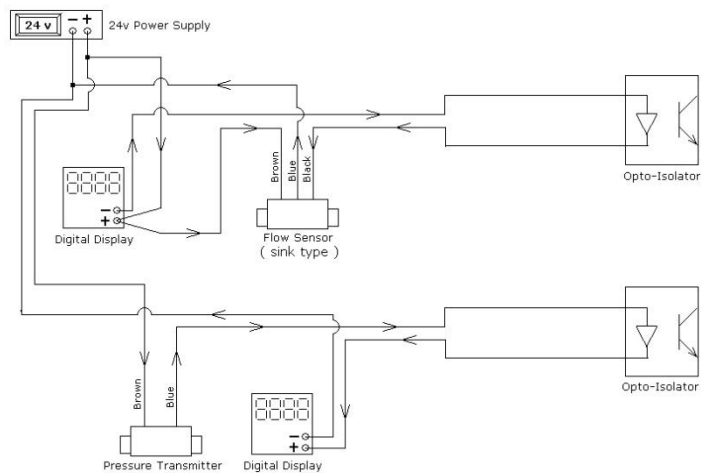


Fig. 11. Schematic diagram to read 4-20 mA output current generated from pressure transmitters and flow sensors electrically isolated from MCU based circuit.

### 3.1 Microcontroller (McU) based electronic circuit designed for this purpose

To isolate the Burkert pressure transmitters and flow sensors from my self-designed electronic circuit, twelve numbers of MC2TE Opto-isolators had been used to monitor the sensor's output current by passing it through the input diodes of each Opto-isolators. It's a well known fact that the response of any such Opto-isolator's photo transistor collector current is not perfectly linear throughout its full range in comparison to the change in input diode current. But still it could give an idea and assurance about flow of water in all such instruments. To achieve this goal, I had passed the photo transistor emitter current through a 150 ohm resistor and fed the voltage drop across these resistors to a multiplexer analog input pins via few operational amplifiers used as buffer amplifier. CD4067B multiplexer IC was used in this circuit that had 16 input pins to monitor input analogue voltages. The schematic diagram of the circuit is shown in Fig.12. The multiplexer IC had four input selection pins those had been coupled to four port pins (P2.0-P2.3) of AT89S52 that could select a particular analogue input line at a time. The output of the multiplexer was connected to an eight bit analogue to digital converter (ADC 0804) via a buffer Op-Amp IC to convert a selected input analogue voltage at some certain moment, determined by the Microcontroller and kept that digitally converted eight bit values in pre-determined memory locations 40h to 4Bh in its RAM. 'WR' pin and 'RD' pins of ADC-0804 was controlled from P2.5 and P2.6 pins of the Microcontroller.

But due to the non-linear response of an opto-isolator,

my initial plan to monitor the sensor's output current variation corresponding to real time water pressure and flow rate did not work well. That produced erroneous results during approximately 30% span of the full range. Hence, finally I had used the digitally converted 8 bit values within the LabVIEW software to generate two state indication - whether the flow was more than minimum threshold limit or not. Green LED indicator ensure safe amount of flow rate and Red LED indicates either no flow of water in that pipe or a flow rate less than the minimum required value (Fig. 13). This threshold value was determined by reading the data byte sent from the McU circuit in different flow rates controlling Legris 90 degree Ball Valves attached on all the twelve pipe lines. A VI *Comparator* was used in LabVIEW for each sensor output with a fixed pre-determined threshold value at one of its two inputs and instead of showing linear changes; it used to produce state change of a LED indicator on LabVIEW front panel.

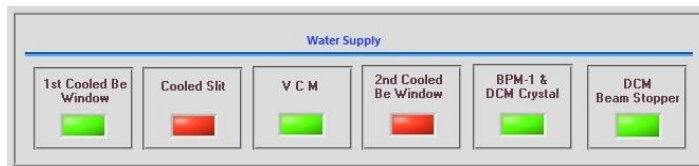


Fig 13. Screenshot of water flow indicators on LabVIEW *Front Panel*.

### 3.2 Communication between the board and LabVIEW GUI

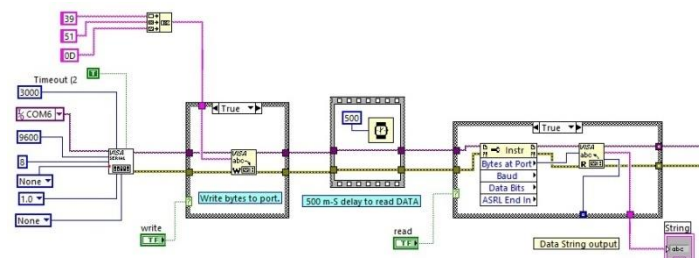


Fig. 14. Part of the *Block Diagram* for programming of RS-232 serial communication with my own McU based circuit through COM-6 of the multi-serial port PCI card.

### 3.3 Summarized function of this circuit step by step

1. Pass through the sensor output 4-20 mA current via Opto-coupler input diode (shown in Fig. 11 and produce a voltage across photo-transistor emitter that is near about linear with respect to the input current variation.
2. Convey this analogue voltage (selected by the multiplexer) produced on a particular opto-isolator towards the ADC chip input.
3. Store the converted digital value in a memory location in the Microcontroller.
4. At the end of a complete acquisition cycle, send a set of twelve bytes to the control PC via RS232 communication.

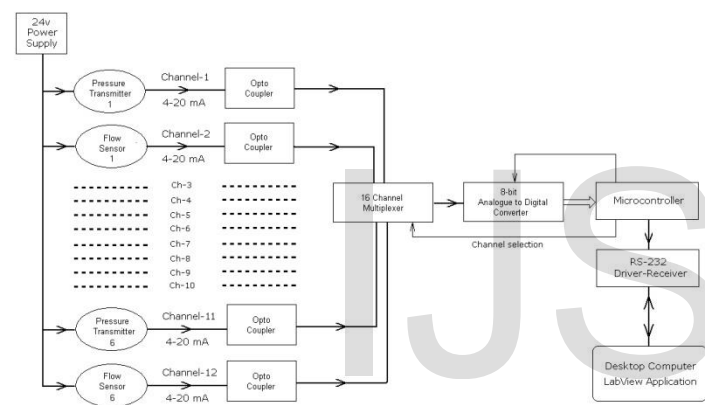


Fig. 12. Schematic diagram of reading data from pressure transmitters and flow sensors to the computer GUI via a Microcontroller based circuit.

All these time dependent ADC output values corresponding to each of the Burkart sensor output current get stored within the memory locations from 40h to 4Bh. All these 8 bit numbers were sent as a bunch of twelve bytes towards the desktop control PC, on request from the GUI via the RS232 serial line.

An assembly language based programme was written (in the year 2011) in KEIL uVision4 IDE and this Microcontroller was programmed by a USB port linked programmer supplied by Robokits India. IC MAX232 (MAXIM) was used to convert the voltage level of RS232 signal to 0 to 5v TTL that is suitable for any digital circuits.

This monitoring and controlling scheme ran uninterrupted for several years up to 2020.

## 5. CONCLUSION

This article has been projected only on technical developmental work to operate and monitor the devices those are ancillary parts of the INDUS2 BL-13 beamline at RRCAT. The target was to describe the process of designing software and building the associated electronic hardware to achieve the goal.

## ACKNOWLEDGMENT

I am very much grateful to Prof. M. K. Sandal for giving me the responsibility of the automation project in the SINP beam line at RRCAT. I would also like to express my sincere thanks to all other group members, like Prof. A. Dutta, Prof. M. Mukherjee, Prof. S. Banerjee, Prof. S. Hazra, Prof. S. Bhunia, Prof. K.S.R. Menon, Prof. M. Mukhopadhyay, Dr. S. K. Mandal and Dr. R. Urkude with whom I worked in different time frame. I am especially thankful to my colleague Mr. Subir Roy, who had fabricated an auxiliary DC power source that was used for the relay driver circuit (mentioned in Fig. 1). And finally, I should express my heartiest gratitude to Prof. T. K. Chini for reading my manuscript and giving his valuable suggestions.

## REFERENCES

- 1 Product Catalogue : High-Speed M Series Multifunction DAQ –16-Bit, up to 1.25 MS/s, up to 80 Analog Inputs, published by National Instruments Corporation, USA.
- 2 DAQ Getting Started Guide, published by National Instruments Corporation
- 3 NI Data Acquisition Catalog from National Instruments ([www.ni.com/india/daq](http://www.ni.com/india/daq))
- 4 Communication Protocol of Single Gauge TPG 261 by PFEIFFER VACUUM ([www.pfeiffer-vacuum.de](http://www.pfeiffer-vacuum.de))
- 5 Multi-Gauge Controller Instruction Manual published by VARIAN Vacuum Technologies.
- 6 Product Catalogue MULTI-PORT Perle Serial Cards, Published by Perle Systems Inc. ([www.perle.com](http://www.perle.com))
- 7 User Manual, Monochromatic Fluorescent Screen and Slit System from Oxford Danfysik (erstwhile website : <http://www.oxford-danfysik.com>)
- 8 User Manual, Cooled Fluorescent Screen Unit from Oxford Danfysik (erstwhile website : <http://www.oxford-danfysik.com>)
- 9 User Manual, Safety Shutter for INDUS beamline at SINP from Oxford Danfysik (erstwhile website : <http://www.oxford-danfysik.com>)
- 10 Product Catalogue of Pressure Transmitter Model-8314 from Burkert Fluid Control Systems ([www.burkert.com](http://www.burkert.com))
- 11 Operating Instructions and Technical Datasheet of Pressure Transmitter Model-8314 from Burkert Fluid Control Systems ([www.burkert.com](http://www.burkert.com))
- 12 Product Catalogue of Flow Sensor for continuous flow measurement Model-8012 from Burkert Fluid Control Systems ([www.burkert.com](http://www.burkert.com))
- 13 Operating Instructions and Technical Datasheet of Type 8012 Paddle-wheel Flow Rate Sensor from Burkert Fluid Control Systems ([www.burkert.com](http://www.burkert.com))
- 14 Product specification of HEF4067B 16-channel Analogue Multiplexer/Demultiplexer from Philips Semiconductor
- 15 Technical Datasheet, MAXIM +5v-Powered, Multichannel RS-232 Drivers/Receivers (<http://www.maxim-ic.com>)
- 16 Technical Datasheet of AT89S52 8-bit Microcontroller from Atmel Corporation, USA (erstwhile website : [www.atmel.com/literature](http://www.atmel.com/literature))

- 17 Technical Datasheet of ADC0804 8-bit A/D Converter from National Semiconductor Corporation
- 18 Technical Datasheet of ULN2003A Darlington Transistor array from Texas Instruments, USA
- 19 Product Catalogue of IC MCT2E Photo Transistor Opto Coupler by Fairchild Semiconductor Corporation ([www.fairchildsemi.com](http://www.fairchildsemi.com))
- 20 <https://knowledge.ni.com/KnowledgeArticleDetails?id=kA03q000000x0QHCA&l=en-GB>
- 21 <https://www.ni.com/en-in/support/documentation/supplemental/06/ni-visa-overview.html>
- 22 <http://www.dept.aoe.vt.edu/~devenpor/aoe3054/manual/inst3/Data%20Acquisition%20with%20Lab.pdf>
- 23 <https://www.rrcat.gov.in/technology/accel/indus2.html>
- 24 [https://en.wikipedia.org/wiki/Raja\\_Ramanna\\_Centre\\_for\\_Advanced\\_Technology](https://en.wikipedia.org/wiki/Raja_Ramanna_Centre_for_Advanced_Technology)
- 25 [https://en.wikipedia.org/wiki/Indus\\_2](https://en.wikipedia.org/wiki/Indus_2)
- 26 <http://www.saha.ac.in/web/spd-facilities/spd-synchrotron-facility/spd-indus-ii>

IJSER