Sputtering Machine Control System

V1.0

Adam Wiesler

This guide is going to be split into multiple sections, as follows

I. Theory of Operation

The purpose of this system is to integrate some of the core functions required to deposit thin films onto a wafer using the sputtering machine. Prior to the installation of this system the user had to operate multiple pieces of equipment. The control system that was installed does not replace these pieces of equipment, but rather monitors and controls them from a unified interface.

The heart of the system is a National Instruments cRIO-9074 embedded controller. This system has 7 I/O modules installed to perform various tasks, including read and write to digital and analog IOs, energize relays, and communicate with serial devices. The cRIO is capable of being run in two modes, FPGA and Realtime. Realtime was chosen for this application as highspeed IO was not required. The cRIO also has an ethernet connection back to a main PC, for control and accessing the datalog files. The cRIO hosts the frontpanel (the user interface that the operator interacts with), and a PC can connect to it through Internet Explorer/Edge, or through LabVIEW.

The cRIO communicates/monitors the following pieces of equipment:

1. Both MDX-1K Magnetron Drives. These connect to the system controller via a DB25 "parallel printer" cable. The controller can turn the drives on, set the output level and ramp time, close interlock, and monitor output current, voltage, and power.
2. Channels 3 and 4 of the MKS 247 Mass Flow Controller. This piece of equipment also connects via a DB25 cable. The system controller can turn the outputs on/off, set flowrate, and monitor flowrate.
3. The IG2000 Ion Gauge Controller is connected via RS232 (connected to Port #1 of the NI 9870 cRIO card). The system controller can monitor the vacuum level, turn the gauge on/off, and degas the tube.
4. All solenoid valves that control:
    a. Turbopump Valve
    b. Roughing Pump Valve
    c. Vent Valve
    d. Nitrogen Valve
    e. Argon Valve

understand. This interface however may not be as familiar to users with experience using the legacy system. To accommodate these users, as well as to provide debugging capabilities, the valves may be manually controlled by moving the switch from "AUTO" to "CLOSED" and "OPEN." Note that when the valves are in these manual control positions, the user will not be able to control them from anywhere else in the user interface, nor that automated sputtering sequencer. In addition, there are no safeguards in place to prevent the user from accidently "dumping" the turbo pumps by venting the system to the atmosphere.

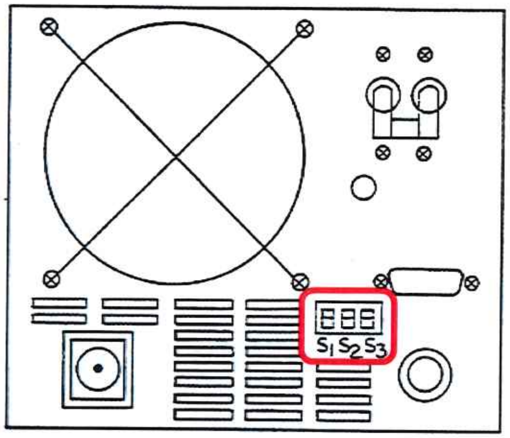
2. **Motor Control:** There is a motor that is used to rotate the internal stage, allowing the used to align the sputtering gun with the target and wafer. There are two relays used to control this motor. One selects the motor direction, and the other turns the motor on. These relays can be controlled automatically from the "Vacuum Control" page when the "AUTO" positions are selected, or by forcing the relays to a certain state using the switches show above. These switches should operate how the legacy system operated with two toggle switches, one to control direction, one to control power. Note that the speed of the motor is selected using an outboard speed controller located in the back of the rack.
3. **Pirani Gauges**: This simply shows the scaled output of the pirani gauge that is selected. To select a different gauge, roll the thumbwheel on the "Pirani Gauge" indicator made by DAIA VACUUM located in the bottom of the rack.
4. **Magnetron Control**: The magnetrons can either be controlled from here, or from the automated sequencer. Again, "AUTO" mode allows for external control, whereas "OFF" and "ON" force the magnetron on or off. When the switch is set to "ON," the programmed output level and ramp time shown in the boxes will be sent to the magnetron drive. These values will not be used any other time. The "Current Out," "Power out," and "Voltage Out" Indicators display the levels that the magnetron drive is actually measuring during its resolution process. The "At Setpoint" light will illuminate when the output level has reached the programmed level, following the ramp period. Note that for the magnetron drive to turn on, the "Interlock OK" signal must be present. This signal is closed when the water chiller is turned on and the flowrate sensor is activated. The magnetron cannot even be turned on from its front panel without this signal present, as damage could occur to the sputtering gun without proper cooling.
5. **Gas Control**: The MKS 247 has two inputs and an output per channel. Channels 3 (Argon) and 4 (N2) can be controlled. The placing the switches in "AUTO" allows for control from the automated sequencer, where as "ON" and "OFF" turn the mass flow controllers on and off. These switches DO NOT control the main, pneumatically actuated valves, mentioned in Section 1 Valve Control. When the switch is in the "ON" position, the flowrate is set from the "X Setpoint" Control. The "X Output" indicators display the scaled output from the Mass Flow controllers. These values should be similar, but may not be identical.
6. **ION Gauge**: The ION Gauge is predominantly controlled from this page. Selecting "AUTO" mode will cause the ION Gauge to turn on at startup, off when a sequence is running, and then will get turned back on when the sequence is over. To degas the tube, force the ION Gauge "ON" and click the "Degas" button. The vacuum level is displayed below the controls.

the front panel. It is for this reason that the power level units on the system controller are a percentage rather than Volts, Amps, or Watts.

In order for the drives to operate, the interlock circuit must be closed by the coolant flow switch. Closing the coolant flow switch turns a relay on within the system controller, and closes the interlock loop of both magneton drives.

All values of the drives can be monitored remotely at any time, regardless if they are remotely controlled or not. In order to be remotely controlled, one must do the following:

From the MDX-1K manual, Page 11:



Switch S1-RAMP.	This switch changes the ramp from 1-10.0 seconds (switch in upper position) to 1-10.0 minutes (switch in lower position).
Switch S2-REMOTE PROG.	This switch changes the program control from the front panel control (switch in the upper position) to user connector control (switch in the lower position). The user connector is used for both level programming (A.XLEVEL) and for Ramp programming (A.XRAMP).
Switch S3-REMOTE ON.	This switch changes the OUTPUT ON control from the front panel (switch in the upper position) to the user connector (switch in the lower position).

Figure II.2.A – Magnetron Drive remote configuration.

As shown in the above manual excerpt, **switch S2- REMOTE PROG and S3-REMOTE ON should be moved to the lower position**. The front panel will no longer be able to control the drive, save for setting the regulation mode.

Additionally, the ramp time units used in the system controller are "seconds," but the actual delay time is based on S1-RAMP. If switch 1 is set to 1-10.0 Minutes, putting a value of "5.5 s" in the Ramp Time

3.8.1 Communications Setup

The XTM/2 has serial communications as a standard feature. Rates from 1200 to 9600 baud are accommodated. Refer to section 2.5.5 on page 2-19 for RS232 connector details.

To configure the remote communication interface, hold down the 0 key during power up. The following set of parameters can then be entered using the digits, enter, and clear keys.

tyPE	(0 = INFICON Checksum, 1 = INFICON no checksum, 2 = SECS, 3 = Datalog)	
	(If SECS is chosen for tyPE the next 5 parameters are accessed):	
	d ID	(Device ID 0-32767)
	t1	(Timer 1 per SECS definition) (0-10.0 seconds)
	t2	(Timer 2 per SECS definition) (0.2-25.0 seconds in 0.2 increments)
	rtrY	(Retry limit per SECS definition) (0-31)
	dUPL	(Duplicate block per SECS definition)
baUd	(0=1200, 1=2400, 2=4800, 3=9600)	
IEEE	(IEEE address, 0-30) - requires optional hardware	

When this list is complete, the RECEIVE message is flashed and the choice will be given to either repeat the list or continue with normal operation. Pressing ENTER will continue with normal operation. Pressing CLEAR will repeat the list.

NOTE: Do not turn the unit off while in the Communications Program Mode, otherwise the new parameter values will not be saved properly.

Figure II.4.A – XTM/2 Serial Configuration Menu

tyPE	1
baUd	3

Table II.4.B – Required Serial Parameters

Electrical Connections:

The rear panel of the system controller should be configured as shown below:

Orange	Roughing Valve
Purple	Turbo Valve
Pink	Load Lock Valve
Grey	Argon Valve
Black	N2 Valve
Blue	AUX Valve
Brown	GND
White	

Table II.C – Pigtail Connections for Solenoid Valve Connections

Black	GND (Likely Unused)
Blue	+24V
Brown	Flow OK

Table II.D – Pigtail Connections for Flow Interlock. Connecting Flow OK to +24V closes the circuit, indicating sufficient flow is present.

Black	Analog Common
White	Pirani #1 (AUX)
Brown	Pirani #0 (Selected)

Table II.E – Pigtail Connections for Pirani Gauges

Black	+24V
Blue	Digital Spare 2
White	Digital Spare 1
Brown	Digital Spare 0

Table II.F – Pigtail Connections for Spare Digital Inputs. These can be used to connect additional sensors in the future.

III. Getting connected

Key Information:

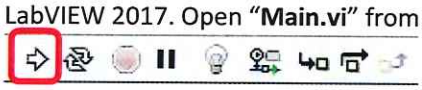
IP address of the cRIO: **192.168.10.99**

FTP location of the datalogs: ftp://192.168.10.99/Datalogs/

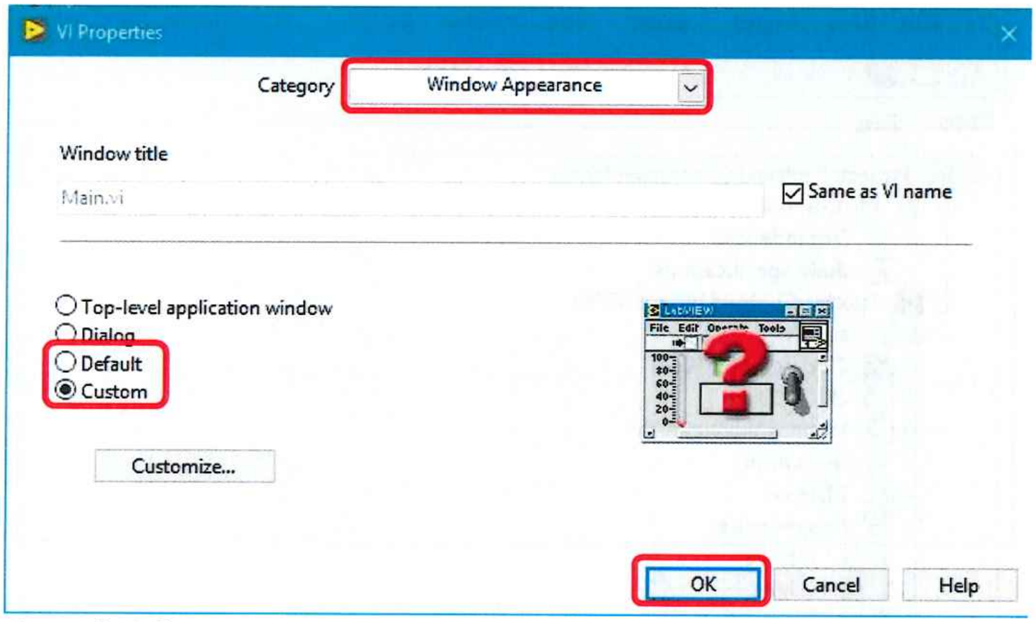
There are two main ways to interact with the LabVIEW program running on the cRIO.

Method 1: Connecting to target to develop application:

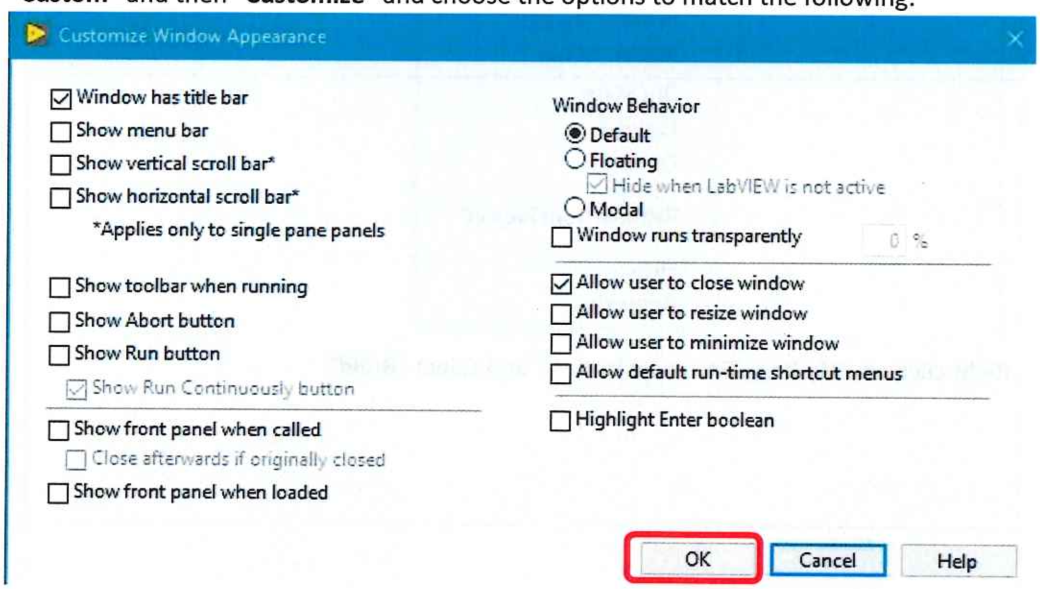
The first way is in "debug" mode, and should only be used when testing and changing the functionality of the system. To use the controller this way, open the project "Supttering_Controller.lvproj" in LabVIEW 2017. Open "**Main.vi**" from there, and press the circled button.



This will launch the debug mode, and allow one to rapidly develop applications. Note that a common practice when creating a control system application is to have a second LabVIEW application on the client PC (Laptop) that sends network commands to the cRIO device. I chose against going this route

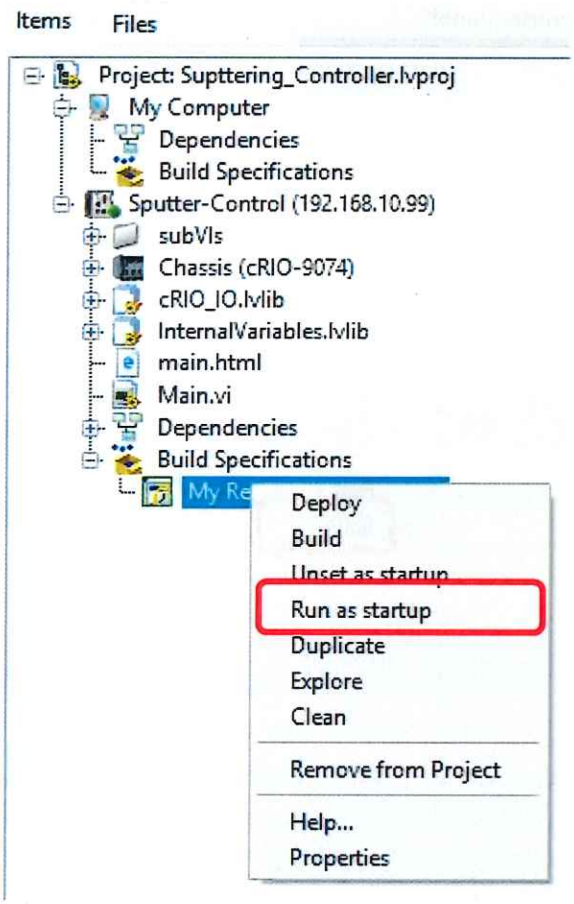


2. Choose “**Window Appearance**”
Select “**Default**” if normal debugging controls are required. Prior to deploying final version, click “**Custom**” and then “**Customize**” and choose the options to match the following:

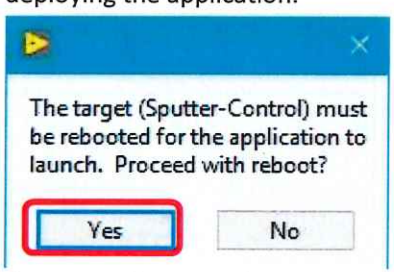


Press “**OK**” for both windows when complete.

Once the application has been developed and debugged, it must be deployed onto the cRIO. This will cause it to run on startup, and be accessible from a web browser. To deploy the application, follow these steps:



2. Next, right click on the target "**My Real-Time Application**" and select "**Run as Startup**"
Note that a power cycle (Power switch on back) may be required to reset the controller prior to deploying the application.



If prompted, restart the Target.

Connecting to already running target:

The second way to connect to the target is to do it without debugging the project. To do this, Open LabVIEW 2017 from the Start Menu.

IV. Vacuum Control

In order for one to load a new wafer in, a few different valves need to be operated. To operate these valves, place "Roughing Valve," "Turbo Valve," and "Load Lock Valve" into the "AUTO" position on the "Manual Control" page. Following this, open the "Vacuum Control" page, as seen in **Figure IV.B**.

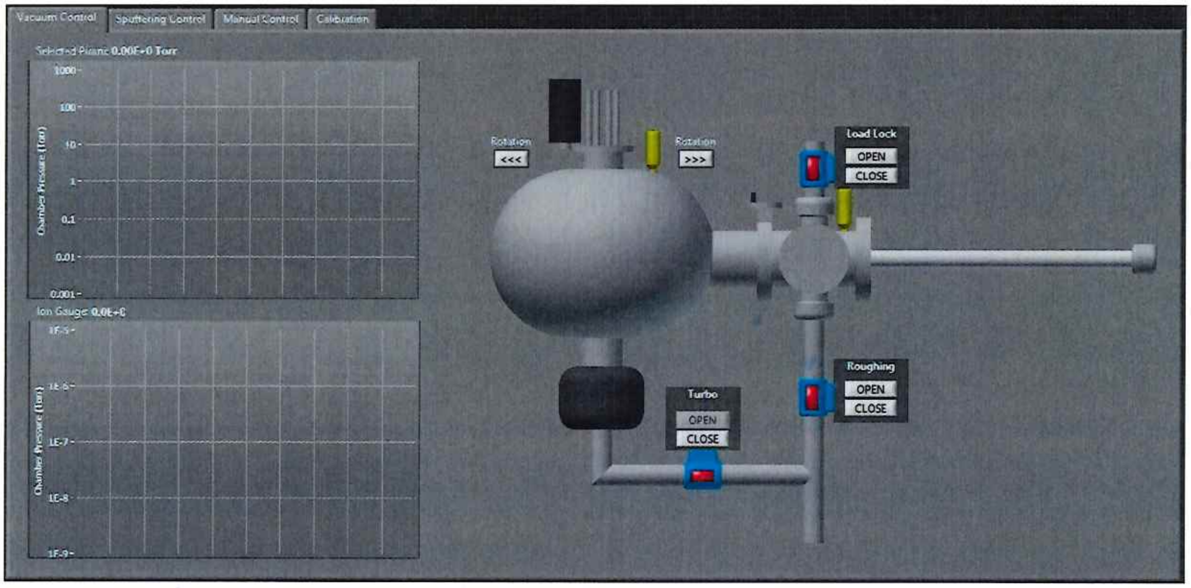


Figure IV.B – Interactive diagram representing system vacuum functions

This page allows for control of the three primary vacuum control valves, as well as control over the rotary stage. There are protective interlocks in place such that the roughing valve and the turbo valve cannot be opened at the same time. Should these both need to be open (for system maintenance or startup) the manual overrides on the "Manual Control" page are NOT interlocked.

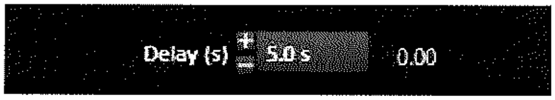
To operate Valves, press "OPEN" to open valve and "CLOSE" to close valve. The colored indicator within the blue valve symbol will change from green (Open) to red (Closed) or vice versa when the system commands the valves to change states. Note that there is NOT positive feedback on the valves. The colored rectangular indicator indicates output state, not physical valve state.

To monitor vacuum status, two graphs are provided. The top graph is the pressure in either the chamber or load lock (selected based on which Pirani gauge is chosen on the Pirani Gauge readout in the rack). The bottom graph is the pressure in the chamber as measured by the ion gauge. This graph only provides real time updates when the ion gauge is switched on, otherwise simply showing the last recorded value.

Finally, to control the rotary stage, two buttons labeled "Rotation" are provided. The leftmost button causes the stage to rotate clockwise when viewed top-down, and the rightmost button rotates the stage counter-clockwise. To operate, click button once to start movement, click again to stop movement. Be sure to monitor the cables and tubes connected to stage when rotating as to avoid snags and collisions.

To set the flowrate desired, type (or use +/- buttons) to select the desired flowrate for each gas.
Argon can be set from 0 to 75 sccm, but anything under ~8 sccm does regulate well
Nitrogen can be set from 0 to 100 sccm, and regulates well down to 5 sccm

2. **Gas Delay:**

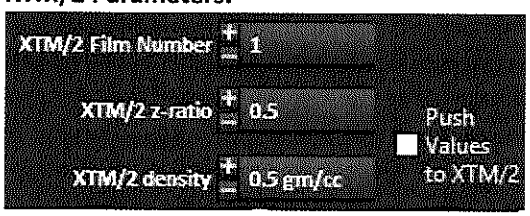


Delay time (in seconds) between the MFCs turning on and the magnetron starting up

3. **Magnetron Control:**

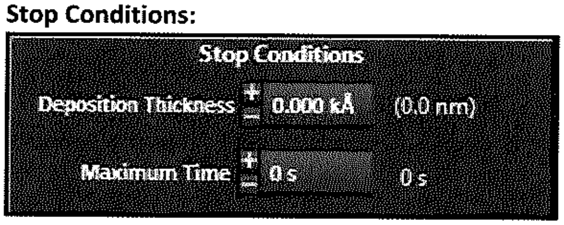
First, the desired magnetron should be selected. [0] is the top MDX-1K in the rack, [1] is the bottom one. If any other magnetron is selected, not physical devices will be controlled. This is useful if one wants to use the gas control and logging features of the controller, but use another power supply (such as an RF supply)
Second, the ramp time should be selected. This is the amount of time that the power supply will take to ramp the output from 0 to the setpoint.
Finally, the power is entered, in percent. If the MDX-1K is in power regulation mode, a value of 50% will result in the power supply trying to maintain a constant 500 watts of power into the gun.
The values to the right are the measured output parameters reported by the MDX-1K.

4. **XTM/2 Parameters:**



The most important parameter is the film number. When the sequence is started, the selected film number will be recalled. If the "Push Values to XTM/2" box is checked, z-ratio and density stored in the unit will be overwritten with the values entered into the boxes above. If the box is not checked, the values stored in the unit will be used.

5. **Stop Conditions:**



The sequence will continue to run until 1) "STOP" button is pressed, 2) The XTM/2 reports a thickness greater than that of the value entered into the above "Deposition Thickness" box (nm

VI. Calibration

There are a few "magic values" used to convert units within the system. These values can be updated with the "Calibration" page:

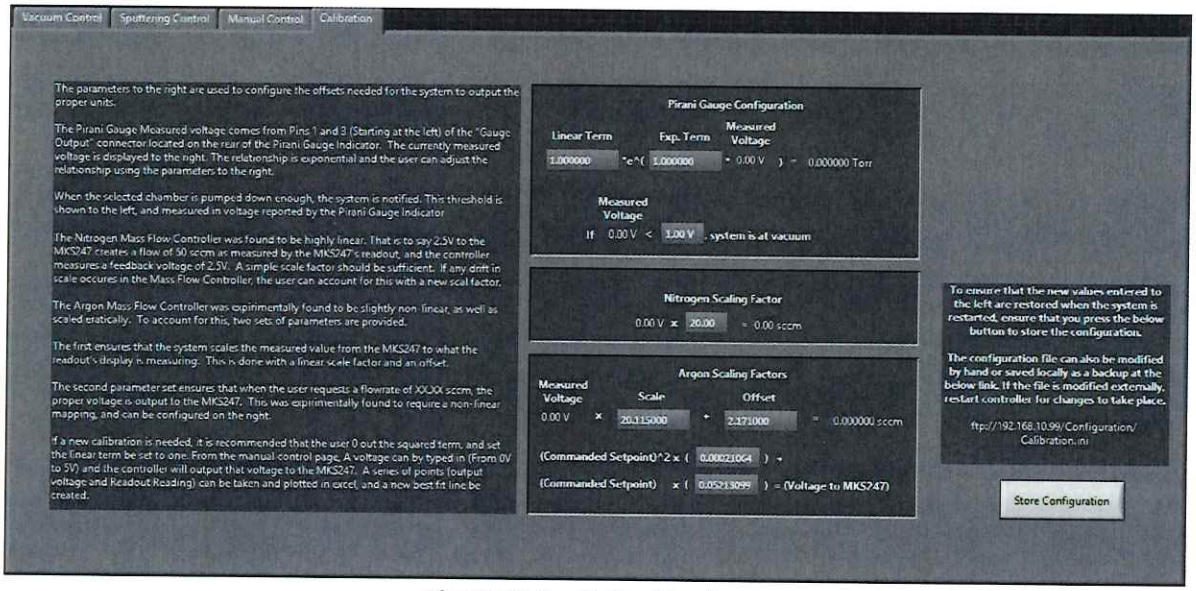
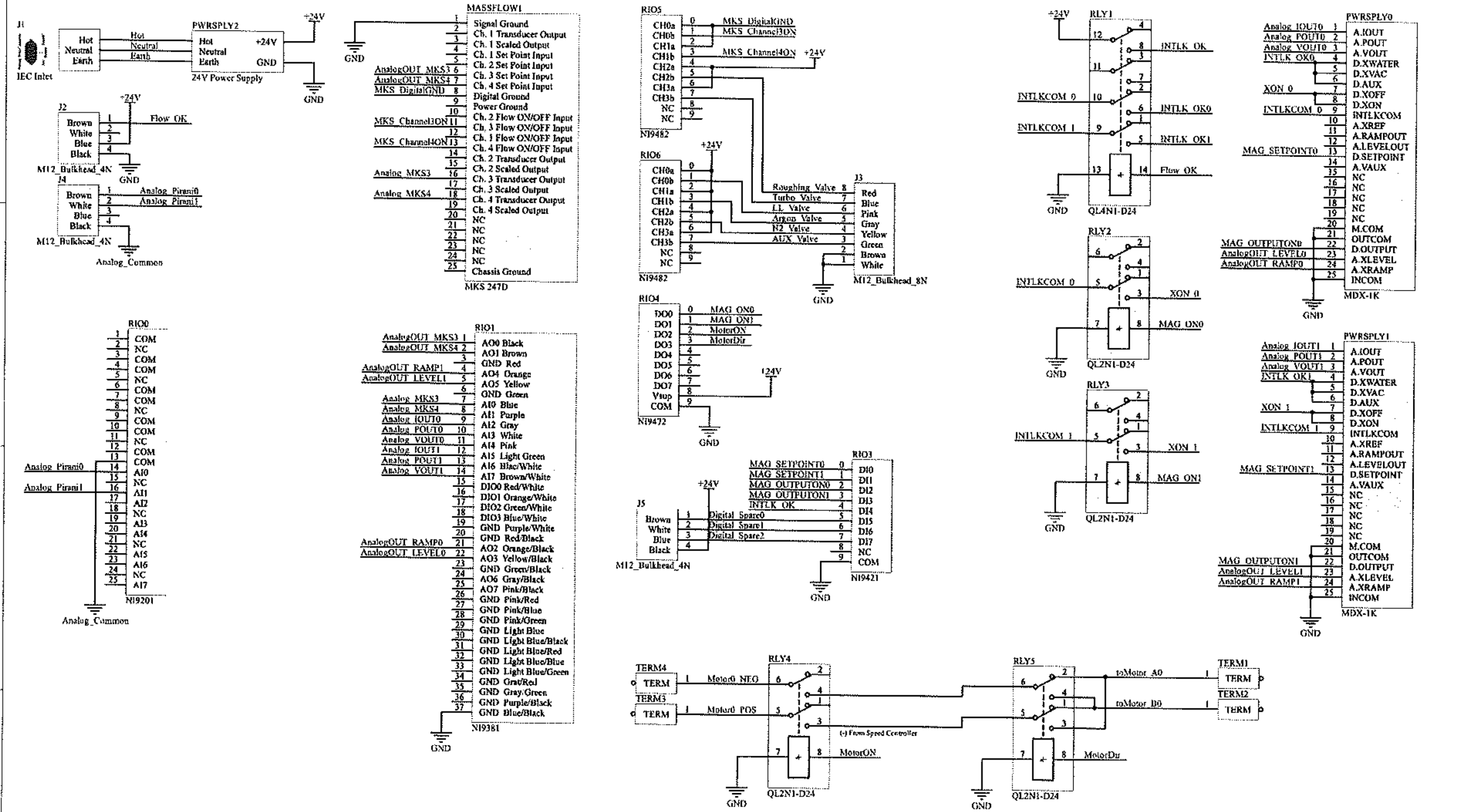


Figure VI.A – Calibration Page

The page itself contains most of the instructions needed. Essentially, the cRIO measures or outputs an Analog voltage (0-5V or -10-10V), and each instrument uses a different scale to convert these voltages into a usable unit such as sccm or Torr. The Pirani interface is simply a 0-2V value, which needs to be mapped to Torr. To do this, excel was used to plot a bunch of points and a best fit line was created. The equation of this best fit line is entered into this page. The same goes for the Argon MFC. The Nitrogen MFC was found to be linear and did not need any additional calibration.

These configuration parameters are stored into an .ini file located at ftp://192.168.10.99/Configuration/Calibration.ini when the "Store Configuration" button is pressed. When the system is started up, the ini file is read in and the parameters updated.



Title		
Sputtering Controller		
Size: B	Number	Revision: V1.1
Date: 11/14/2017		Sheet 1of 1
File: C:\Users\...\SputteringMachine.SchDoc		Drawn By: Adam Wiesler

7.0 USER INTERFACE CONNECTOR

Connector - Subminiature "D" (25 pin)

PIN#	NAME	DESCRIPTION	REFERENCE
1	A.IOUT	Analog signal representing output current	7.2.1
2	A.POUT	Analog signal representing output power	7.2.2
3	A.VOUT	Analog signal representing output voltage	7.2.3
4	D.XWATER	User water interlock	7.2.4
5	D.XVAC	User vacuum interlock	7.2.4
6	D.AUX	User auxiliary interlock	7.2.4
7	D.XOFF	Remote system off command	7.2.5
8	D.XON	Remote system on command	7.2.6
9	INTLKCOM	Interlock common	7.2.7
10	A.XREF	External reference voltage (5.0V)	7.2.8
11	A.RAMPOUT	Analog signal representing ramp program	7.2.9
12	A.LEVELOUT	Analog siganl representing level program	7.2.10
13	D.SETPOINT	Digital indication representing output at setpoint	7.2.11
14	A.VAUX	External voltage (+15V)	7.2.12
15	_____	__________	
16	_____	__________	
17	_____	__________	
18	_____	__________	
19	_____	__________	
20	M.COM	Meter common	7.2.13

7.2.5 **D.XOFF**

The D.XOFF command duplicates the OUTPUT OFF of the front panel. This function overrides all other commands and forces the Magnetron Drive to turn off by opening the main contactor.

7.2.6 **D.XON**

D.XON command allows remote turn on of the Magnetron Drive. To use this command, the REMOTE ON must be selected on the rear panel. See Figure 1. This transfers the OUTPUT ON command to D.XON. A momentary contact closure of D.XON to INTLKCOM 9 will cause the Magnetron Drive to turn on if D.XOFF is connected through a contact closure to INTLKCOM. See Diagram 3. A two-wire command is possible with D.XON and D.XOFF connected together. If this is done, both must be connected to INTLKCOM continuously to turn on the Magnetron Drive. See Diagram 4.

7.2.7 **INTLKCOM**

All interlock connections are referred to INTLKCOM, a dedicated ground that returns to the internal system ground, the chassis ground, and finally safety ground.

7.2.8 **A.XREF**

The A.XREF connection provides the user with an accurate 5V reference (5V $\pm$ 10mV). Reference A.XREF to INCOM.
Note: Do not load the A.XREF to more than 5mA. Source impedance is 100 ohms.

7.2.9 **A.RAMPOUT**

The A.RAMPOUT connection provides a fully buffered 0-5V output signal representing the amount of time for the output ramp. 5V equals 10.0 seconds or minutes, whichever is selected. See Figure 1. Source impedance is 100 ohms.

7.2.10 **A.LEVELOUT**

The A.LEVELOUT connection provides a fully buffered 0-5V output signal representing the presently programmed setpoint of the Magnetron Drive. 5V equals max setpoint. Reference A.LEVELOUT to M.COM. Source impedance is 100 ohms.

7.2.11 D.SETPOINT

D.SETPOINT is an output signal that duplicates the SETPOINT light indication on the front panel. D.SETPOINT goes low when the output setpoint has been reached. D.SETPOINT should be referenced to OUTCOM. D.SETPOINT will flash at a rate of approximately 3.5Hz. When the output is not at setpoint, it will flash at approximately 15Hz when the output is ramping.

7.2.12 A.VAUX

The A.VAUX connection is a user available + 15V referenced to OUTCOM. This output is internally limited at 100mA.

7.2.13 M.COM

All meter connections are referenced to M.COM, a dedicated ground that returns to internal system ground, then chassis ground, and finally safety ground.

7.2.14 OUTCOM

Ground return used as a reference for MDX drive that parallels front panel status indicators. A dedicated ground that returns to the internal system ground, then chassis ground, and finally safety ground.

7.2.15 D.OUTPUT

D.OUTPUT is an output signal that duplicates the OUTPUT light indication on the front panel. The OUTPUT light on the front panel will illuminate when the OUTPUT is enabled. D.OUTPUT goes high when the OUTPUT is enabled. Reference D.OUTPUT to OUTCOM. Source impedance is 100 ohms.

7.2.16 A.XLEVEL

The A.XLEVEL connection allows the user to program output level from an external source. See Diagram 6. The signal should be 0 to 5V, with 5V being maximum output. To enable this function, REMOTE PROGRAM must be selected. See Figure 1. Reference A.XLEVEL to INCOM. Source impedance is 100 ohms.

User Plug

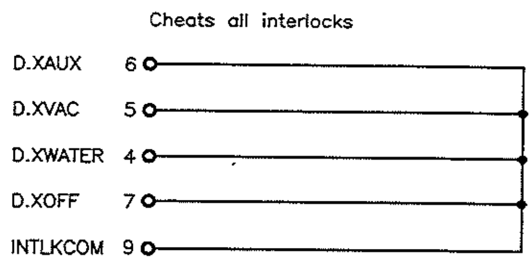


Diagram 1. Cheater Plug

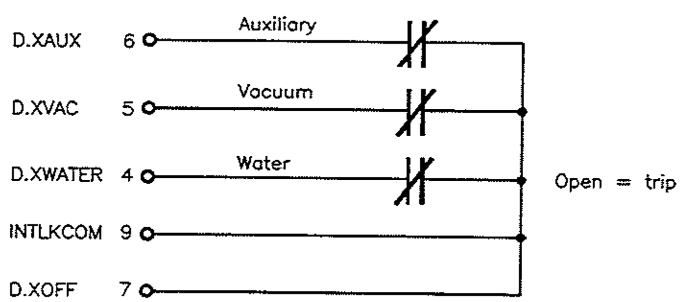


Diagram 2. Normal Interlock Connection

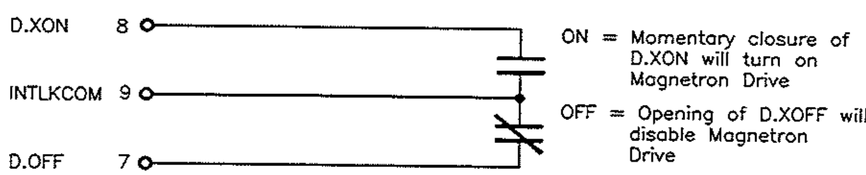


Diagram 3. Three-wire Control Connection

8.0 FRONT PANEL CONTROLS

8.3.1 POWER

The power button turns on the internal power of the power supply.

8.3.2 OUTPUT OFF

The OUTPUT OFF button will turn off the Magnetron Drive.

8.3.3 OUTPUT ON

The OUTPUT ON button turns on the Magnetron Drive if the front panel mode is selected, a regulation mode has been selected and all interlocks are satisfied. If a setpoint value has previously been programmed, the MDX will go to that value when turned on.

8.3.4 REGULATION; POWER, CURRENT, VOLTAGE

The MDX Magnetron Drive allows three modes of regulation; POWER, CURRENT or VOLTAGE. The current mode is selected by pressing CURRENT, the power mode by pressing POWER, and the voltage mode by pressing both POWER and CURRENT simultaneously. The user can change modes only when the output has been turned off.

8.3.5 LEFT DISPLAY

The LEFT DISPLAY allows continuous monitoring of the Regulation Mode. When the Regulation Mode is changed, the parameter that is monitored changes to the new mode.

8.3.6 STATUS INDICATORS

8.3.6.1 ARC

The ARC LED flashes when an arc is sensed or if the ARC-OUT™ circuit is activated.

8.3.6.2 SETPOINT

The SETPOINT LED turns on when the output reaches the pre-selected setpoint. It will flash if current, voltage or power exceed their maximum limits or if the output cannot reach the programmed level.

8.3.9 RAMP

The RAMP knob allows the user to preprogram the amount of ramp time (time from 0 output to preprogrammed level). This can be programmed for either 1-10.0 seconds or 1-10.0 minutes. See Figure 1.

8.3.10 RIGHT DISPLAY

The RIGHT DISPLAY allows continuous monitoring of the following parameters in conjunction with the 'ACTUAL' or 'SETPT' switches.

8.3.10.1 KW

When the KW LED is on, the DISPLAY is monitoring either output kilowatts if the ACTUAL LED is on or is monitoring the power setpoint if the SETPOINT LED is on and the supply is in the POWER REGULATE MODE. Press SETPT or press ACTUAL switch.

8.3.10.2 VOLTS

When the VOLTS LED is on, the RIGHT DISPLAY is monitoring output voltage if the ACTUAL LED is on or is monitoring the VOLTAGE REGULATION SETPOINT if the SETPOINT LED is on and the supply is in the VOLTAGE REGULATE MODE. Press SETPT or ACTUAL switch.

8.3.10.3 AMPS

When the AMPS LED is on, the RIGHT DISPLAY is monitoring output current if the ACTUAL LED is on or is monitoring the CURRENT REGULATION setpoint if the SETPOINT LED is on and the supply is in the CURRENT REGULATE MODE. Press SETPT or ACTUAL switch.

8.3.10.4 MINUTES OR SECONDS

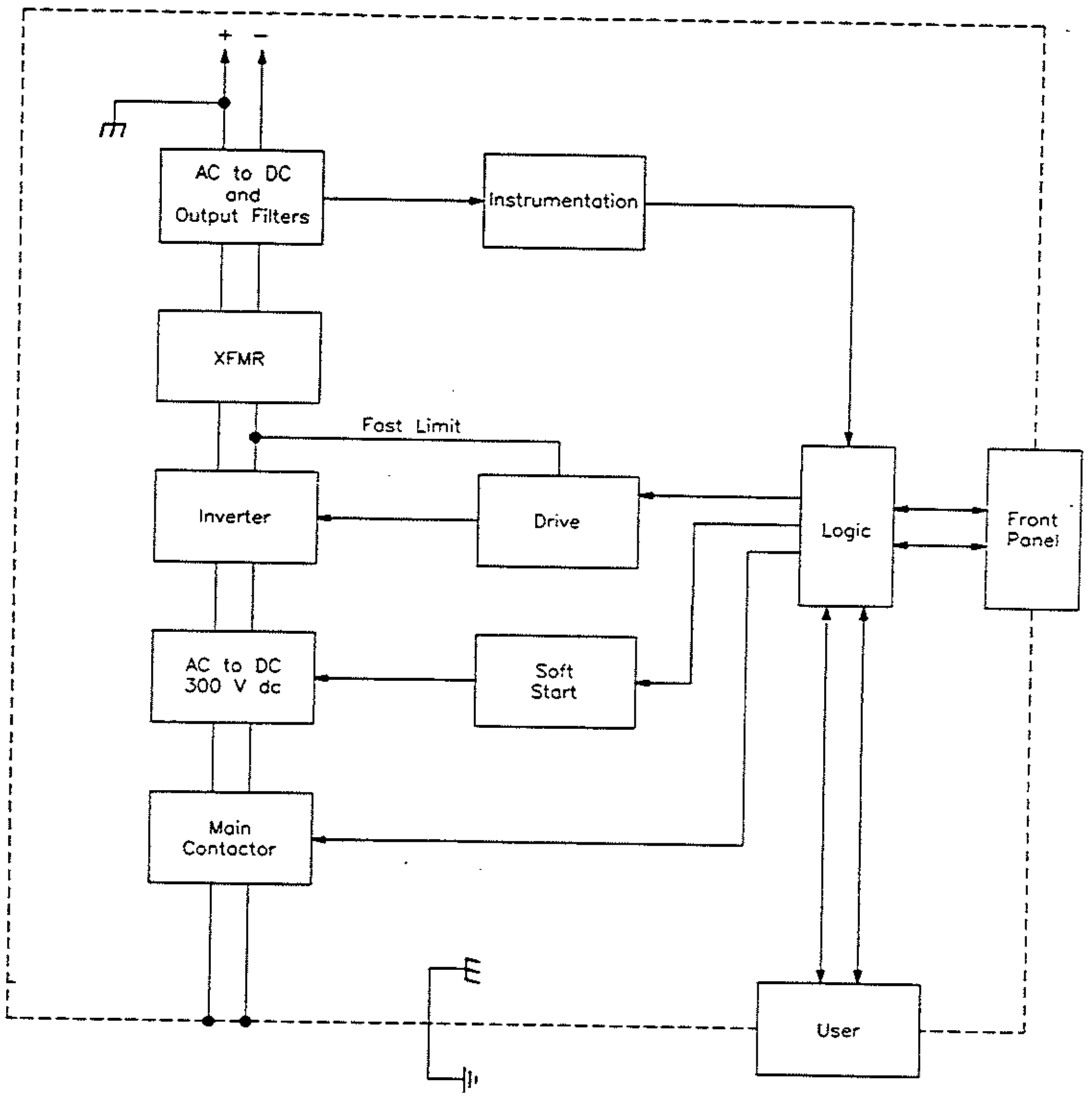
When the MINUTES or SECONDS and SETPOINT LEDS are on, the RIGHT DISPLAY shows the ramp setpoint.

8.3.11 SETPT

The SETPT switch allows the user to check programmed setpoints. If the RIGHT DISPLAY indicates MINUTES or SECONDS, pressing the SETPT switch allows the user to see the programmed REGULATION mode setpoint. If the RIGHT DISPLAY indicates KW, VOLT or AMP, pressing the SETPT switch allows the user to check the programmed regulation MODE setpoint.

10.0 PRINCIPLES OF OPERATON

Block Diagram:



Connectors and Cables

The 247 unit's two Interface connectors and four MFC connectors are located on the rear panel of the unit (refer to Figure 6, page 43).

When the 247 is purchased as part of a complete system including MFCs, all of the required interface cables are supplied. When purchased separately, the interface cables must be specifically ordered. The system interface cables are listed in Table 5, page 20.

Interface Connector P6 (Channels 1 to 4)

The 25-pin male Type "D" connector, located on the rear panel (refer to Figure 6, page 43) provides the communications link to and from the unit, including the connection to the scaled transducer outputs, the lines to turn the flow on and off, and the set point input lines which remotely set the flow rate of the MFCs.

Interface Connector P6 (Channels 1 to 4) Pinout			
Pin	**Assignment**	**Pin**	**Assignment**
1	Signal Ground	14	Ch. 2 Transducer Output
2	Ch. 1 Transducer Output	15	Ch. 2 Scaled Output
3	Ch. 1 Scaled Output	16	Ch. 3 Transducer Output
4	Ch. 1 Set Point Input	17	Ch. 3 Scaled Output
5	Ch. 2 Set Point Input	18	Ch. 4 Transducer Output
6	Ch. 3 Set Point Input	19	Ch. 4 Scaled Output
7	Ch. 4 Set Point Input	20	No Connection
8	Digital Ground	21	No Connection
9	Power Ground	22	No Connection
10	Ch. 2 Flow ON/OFF Input	23	No Connection
11	Ch. 3 Flow ON/OFF Input	24	No Connection
12	Ch. 1 Flow ON/OFF Input	25	Chassis Ground
13	Ch. 4 Flow ON/OFF Input		

Table 7: Interface Connector P6 (Channels 1 to 4) Pinout

Note

The "No Connection" pin assignment refers to a pin with no internal connection.

MFC Connectors (J1 - J4)

The four 15-pin Type "D" connectors (J1 through J4), located on the rear panel (refer to Figure 6, page 43), provide the connection for the mass flow controllers. Each connector provides the necessary power and set point voltages, and receives the flow output signal.

MFC Interface Connectors (J1 - J4) Pinout	
Pin	**Assignment**
1	No Connection
2	Flow Input Signal
3	No Connection
4	No Connection
5	Power Ground
6	-15 Volts
7	+15 Volts
8	Set Point Output Signal
9	No Connection
10	Input Stage Output
11	No Connection
12	Signal Ground
13	No Connection
14	No Connection
15	Chassis Ground

Table 9: MFC Interface Connectors (J1 - J4) Pinout

Note

1. The "No Connection" pin assignment refers to a pin with no internal connection.
2. An extra power supply is needed if using more than two 1559 MFCs with one 247 unit.

Set Point Signal

The set point signal that is sent to each MFC through connectors J1 to J4 may be generated in a variety of ways:

- *Manually* using independent gas flows or by ratioing the gas flows for one to three channels to the flow in Channel 1
- *Externally* using a set point signal from an external controller, or by ratioing gas flows based on the set point signal from an external controller and measurements from a pressure transducer
- *Remotely* using TTL logic control

Set Point Signal Source

The flow rate is determined by the magnitude of the set point signal with +5 V corresponding to full scale flow. The set point signal can be generated by:

- An internal +5 V reference
- A ratio signal from Channel 1 or an external controller
- An externally applied voltage

The source of the set point signal is selected by the three position SET POINT SOURCE SWITCH on the front panel (refer to Figure 5, page 40), as either FLOW, RATIO, or EXT. The FLOW and RATIO positions of this switch are driven by the output of the SET POINT CONTROL; the EXT position is driven by an externally applied voltage.

The output of the SET POINT CONTROL is driven by an internal dipswitch (S15), located on the rear of the Main PC board. The 247 unit is initially configured so that the ratio set point signal is based on the Transducer Output of Channel 1 (the internal reference). To change the configuration so that the source of the set point signal is based on the External Ratio Amplifier, you must change the dipswitch settings in S15. Refer to *How To Change the Dipswitch Settings*, page 64, for more information.

Set Point Function with External Flow Control

The SET POINT SOURCE SWITCH must be set to the RATIO position, when using an external set point source.

Individual Gas Flows

This mode of operation enables you to control individual gas flows using a set point signal from an external command. A 0 to 5 VDC signal from an external source is received at Interface Connector P6, where it is routed by the SET POINT SOURCE SWITCH to each MFC. Its application to the MFC is the same as that described in *Individual Gas Flows*, page 37.

Note that each channel has its own external set point line. Any or all channels may have their set points or flow driven from the external source. Those that are not may be adjusted using the controls on the 247 unit, as described in *How To Manually Control Individual Gas Flows,* page 59.

Pressure Control with Ratioed Gas Flows

In this type of operation, the pressure in a chamber is maintained by controlling the ratio of gas flows, based on a set point signal from an external controller and measurements from a pressure transducer. This system configuration requires the 247 unit, an external controller, and a pressure transducer, as shown in Figure 4, page 28. More than four gases may be controlled by adding a second 247 unit to the system.

Note that any or all channels may be used to flow gas to maintain pressure with a preset ratio of flows. Any channel that is not used in this way may be used independently.

Note Any controller and pressure transducer may be used provided the signal that enters the 247 unit goes *positive* with increasing flow (correct polarity). Throughout this manual, the MKS Type 250 Pressure/Flow Controller and Type 127/227 Baratron Pressure Transducers are used for example only.

In this mode of operation, the 247 unit receives a signal from the controller called a pressure control signal (PCS). This signal goes to an appropriate level from 0 to 10 VDC to drive the pressure signal to equal its set point signal (within the 250 controller). The PCS voltage enters the 247 unit at Interface Connector P5, is buffered and amplified, and routed to the RATIO position of the SET POINT SOURCE SWITCH. From this point the paths are the same as those described in *Ratioed Gas Flows*, page 37.

Front Panel Controls

Figure 5 shows the location of the controls on the front panel of the 247 controller.

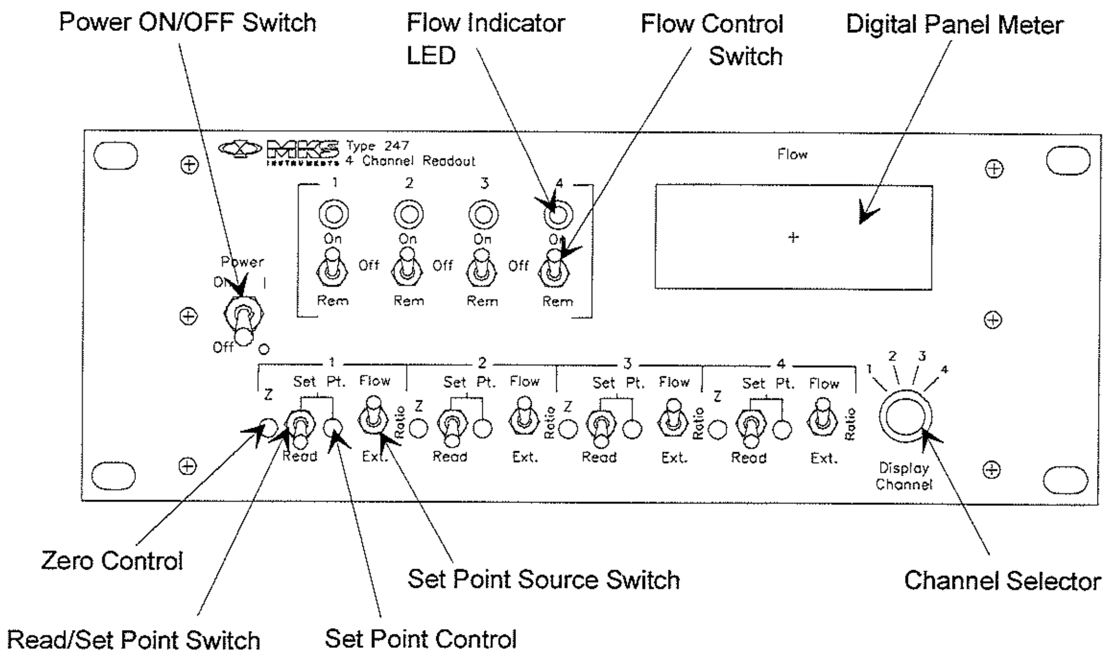


Figure 5: Front Panel Controls

Power ON/OFF Switch

The Power switch controls power to the 247 unit and all attached MFCs.

Flow Indicator LED

This green LED indicates that the set point signal has been applied to the MFC. It does not mean that flow is occurring or that its value is correct.

Set Point Control

This 20-turn potentiometer sets the set point level when the Set Point Source Switch is in the FLOW or RATIO position. The ranges are:

FLOW Position: ± 0.1 to 100% of Full Rated Flow

RATIO Position: ± 0.1 to 100% of Channel 1 Flow/Ext. Ratio Signal

Read / Set Point Switch

This spring loaded switch allows you to read, from the Digital Panel Meter, either the flow rate or the set point value (which may be going to the MFC through the front panel flow switch). This allows you to check or set the MFCs zero, check or set the set point level, and check for an agreement between flow and set point when the MFC is so commanded.

The Scaling Controls on the rear panel (refer to Figure 6, page 43) must be properly set for the meter to display a *direct* set point reading, in sccm or slm. Refer to *Scaling Controls*, page 46, for more information.

Zero Control

This 20-turn potentiometer is used for fine zero adjustment. It has a limited range of ±3% of FS; therefore, larger adjustments must be made with the zero control on the MFC.

Decimal Point Selector Switches

These switches, one for each channel, set the decimal point for the Digital Panel Meter on the front panel.

The position of the decimal point is determined by the full scale range of the MFC in use. A 100 sccm mass flow controller requires the decimal point to be positioned as "100.0" (display at full rated flow).

Line Voltage Selector

The Line Voltage Selector configures the 247 unit to accept either 115 or 230 VAC input voltage. The voltage selected is visible in the panel cutout. Refer to *How To Set the Line Voltage,* page 31, for more information.

Caution **The Line Voltage Selector on the 247 unit must be set to the proper input voltage *before* you connect the power cord and turn on the power. Otherwise, the unit will be severely damaged.**

Fuse

The fuse protects the internal circuitry of the 247 unit; both sides of the line are fused. The fuse values are listed in Table 6, page 30.

Caution **Disconnect the power cord from the 247 unit *before* you replace the fuse, to avoid any damage.**

AC Line Cord

The AC Line Cord provides 115 or 230 VAC power to the 247 unit. For protective earthing, plug the power cord into a properly grounded outlet.

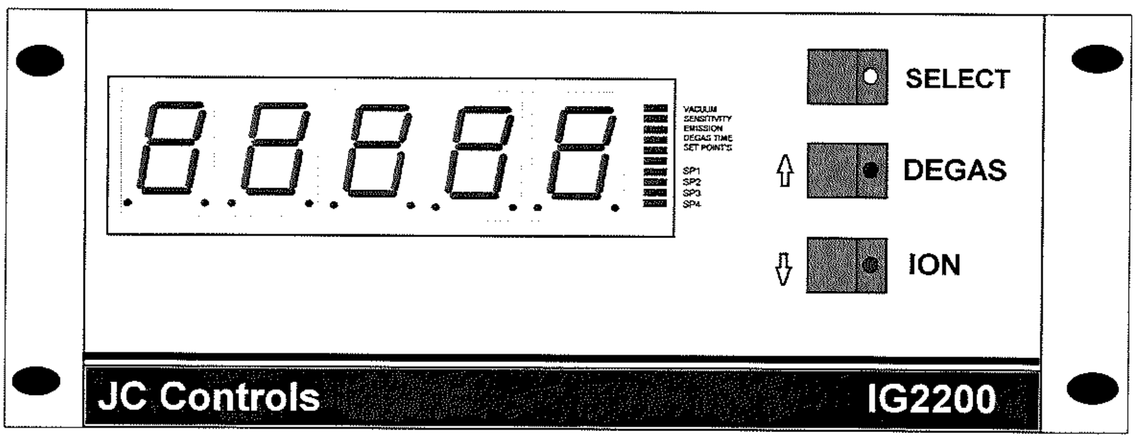
Interface Connector J6 - Channels 1 to 4

This 25-pin male Type "D" connector provides the communications link to and from the unit, including the connection to the scaled transducer outputs, the lines to turn the flow on and off, and the (external) set point input lines which remotely set the flow rate of the MFCs.

Refer to Table 7, page 32, for the Interface Connector J6 pinout.

IG2200 Ionization Gauge Controller

Instruction Manual



JC Controls

INDEX

RECEIVING - DAMAGED / MISSING PARTS

Confirm that the shipped controller is the same as listed on the packing list and that it includes all the materials and options that were ordered. If materials are damaged, the carrier that delivered the carton or cartons must be notified in accordance with the Interstate Commerce Commission regulations - normally within 15 days. A damage claim must be filed with the carrier, do not call the manufacturer to file a claim as all claims must be made by the recipient through the delivering carrier. JC Controls will be happy to help with shipping identification numbers, routing and/or shipment tracing.

Any damaged materials including all shipping containers, boxes and packing materials should be kept for the carriers inspection.

Contact the manufacturer :

JC Controls
1522 Second Ave
Walnut Creek, CA 94596
(925) 939-8877

if the shipment is not identical to the packing list or not what was ordered.

International Shipments

Inspect all materials received for shipping damage. Check to be certain your shipment includes all materials and controller options ordered. Any items damaged must be reported to the carrier making the delivery to the customs broker within 15 days of delivery.

WARRANTY

The JC Controls IG2200 Ionization Gauge Controller is guaranteed for **Three years** against defects in parts, materials and workmanship. Any misuse or attempts to reprogram the controller during the warranty period will void the warranty. No other warranties are expressed or implied. If the unit malfunctions during the warranty period, return it to JC Controls and it will be repaired at no charge. Please include a written statement of the problem with a contact name and phone number.

IG2200 SPECIFICATIONS

Power Requirements :	95 - 125 VAC (50/60 Hz), 185 Watts 200-250 VAC (50/60 Hz),185 Watts - OPTIONAL
Size:	3 ½" H (90 mm), 8" W (204 mm), 10.5" D (267 mm)
Weight:	11 Lbs.
Temperature Range :	0 - 40° C
Ion Gauge :	
Type	Bayard - Alpert
Range	9.9×10^{-4} to 2.0×10^{-9} Torr
Sensitivity	1/Torr to 80/Torr (Factory set to 10/Torr)
Emission Current	1.0 mA o 25.5 mA (Factory set to 10.0 mA)
Collector Potential	0 VDC
Grid Potential	+180 VDC
Filament Potential	+30 VDC
Degas	I^2R, 7V, 8A max;
Display Modes:	
Vacuum	Full range of Ion Gauge Tube
Sensitivity	Adjustable from 1/Torr to 80/Torr
Emission Current	Adjustable from 1.0 mA to 25.5 mA
Degas Time	Timer Adjustable from 1 to 60 Minutes
SP1	Adjustable from 9.9×10^{-4} to 1.0×10^{-10} Torr
SP2	same as SP1
SP3	same as SP1
SP4	same as SP1
Setpoints:	2A @ 100 VAC SPST Relay
RS-232:	9 pin RS-232 Data Port

OPERATION

Controls

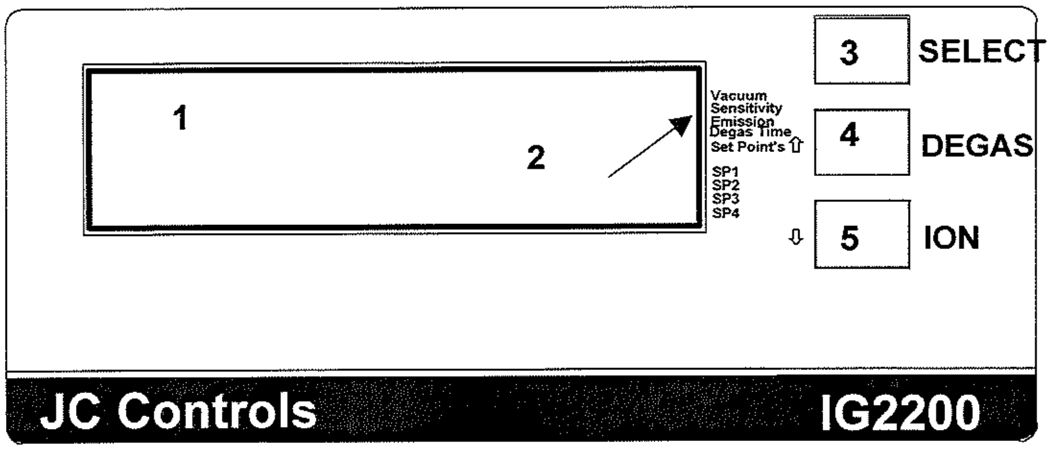


Figure 1

1. Main Display
2. Mode & Setpoint indicator
3. Select Switch
4. Degas / (+) Switch
5. Ion Gauge / (-) Switch

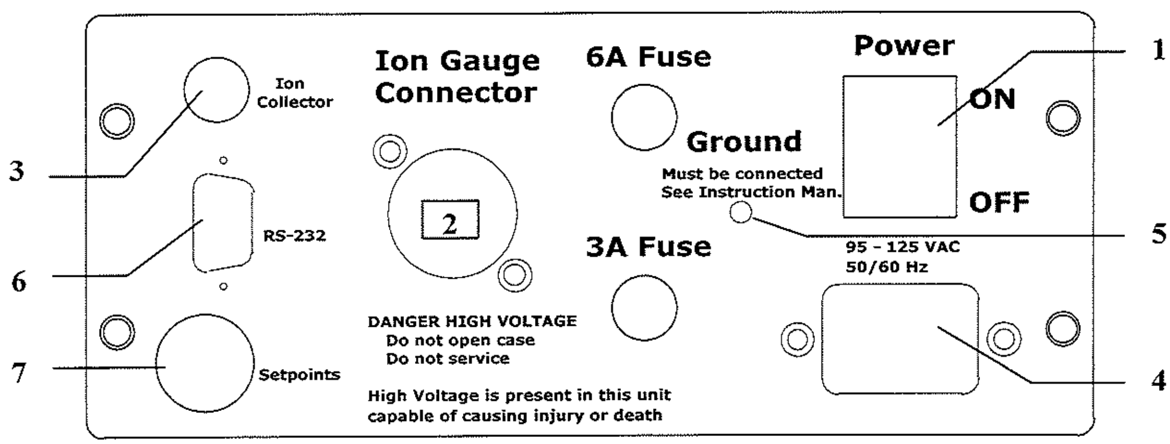


Figure 2

1. Power On/Off Switch
2. Ion Gauge Connector
3. Collector BNC Connector
4. Power Connector
5. Grounding Screw
6. RS-232 Connector
7. Setpoint Connector

Here is a list of the modes and what they do:

Mode	Select LED	Operation	Display Units
1	Vacuum	Display Ion Gauge Vacuum	#.#-## Torr
2	Sensitivity	Display/Adjust Sensitivity	## 1/Torr
3	Emission	Display/Adjust Emission Current	##.# mA
4	Degas Time	Display/Adjust Degas Time	## minutes
5	Setpoint /SP1	Display/Adjust Setpoint 1	#.#-## Torr
6	Setpoint /SP2	Display/Adjust Setpoint 2	#.#-## Torr
7	Setpoint /SP3	Display/Adjust Setpoint 3	#.#-## Torr
8	Setpoint /SP4	Display/Adjust Setpoint 4	#.#-## Torr

Table 1

Sensitivity Adjustment

Press the Select Switch once to enter the Sensitivity Adjustment mode. The sensitivity value is displayed on the main display. To adjust the value, press the "DEGAS/(+)" switch to increase the value by 1 /Torr, or press the "ION/ (-)" switch to decrease it. The range of adjustment is from 1 to 80 /Torr.

There are 2 factors in ion gauges that have a sensitivity. The first is the sensitivity of the gauge tube and the second is the sensitivity of the gas in the vacuum system. These two values should be multiplied together to form the sensitivity value. For more information on sensitivity see page 11.

*Sensitivity = Tube Sensitivity * Gas Sensitivity*

Emission Adjustment

Press the Select Switch twice to enter the Emission Adjustment mode. The emission current value is displayed on the main display. To adjust the value, press the "DEGAS/(+)" switch to increase the value by 0.1 mA, or press the "ION/(-)" switch to decrease it.. The range of adjustment is from 1.0 to 25.5 milliamps.

The controller will automatically switch to a 1/10 emission setting when it is in the lower pressure ranges. This will help increase the life of the ion gauge tube.

There is no real reason for changing this adjustment. On older ionization controllers the emission adjustment was used to correct for different sensitivity. The IG2200 has a sensitivity adjustment and it should be used to change sensitivity.

Degas Timer

Press the Select Switch 3 times to enter the Degas Time Adjustment mode. The degas time value is displayed on the main display. To adjust the value, press the "DEGAS (+)" switch to increase the value by 1 minute, or press the "ION (-)" switch to decrease it. The range of adjustment is from 1 to 60 minutes. If you enter the degas timer mode while

Ion Gauge Shut Down Codes

When the IG2200 turns off the ion gauge tube, the controller will display a CODE# on the main display. This will stay on the display for about 2 seconds. Here is the list of the CODE#'s.

CODE1

The Ion Gauge shuts off because it can not get or hold the Emission Current.

Possible Problems: Vacuum is to low
Ion Gauge Cable is disconnected
Filament Fuse is blown

CODE2

The Ion Gauge shuts off because it can not establish Collector Current.

Possible Problems: Vacuum is to high
Ion Collector BNC is disconnected

CODE3

The Ion Gauge shuts off because the vacuum lower than 9.9×10^{-4}. This is the normal shut down mode when bringing the pressure up in the vacuum system.

CODE4

There is a problem with the EEPROM. If this Code is displayed call JC Controls for repair.

CODE6

There is a problem with the RS-232 receiver routine.

Possible Problems: RS-232 Cable is loose or broken
Baud Rate or Communication Setting are wrong

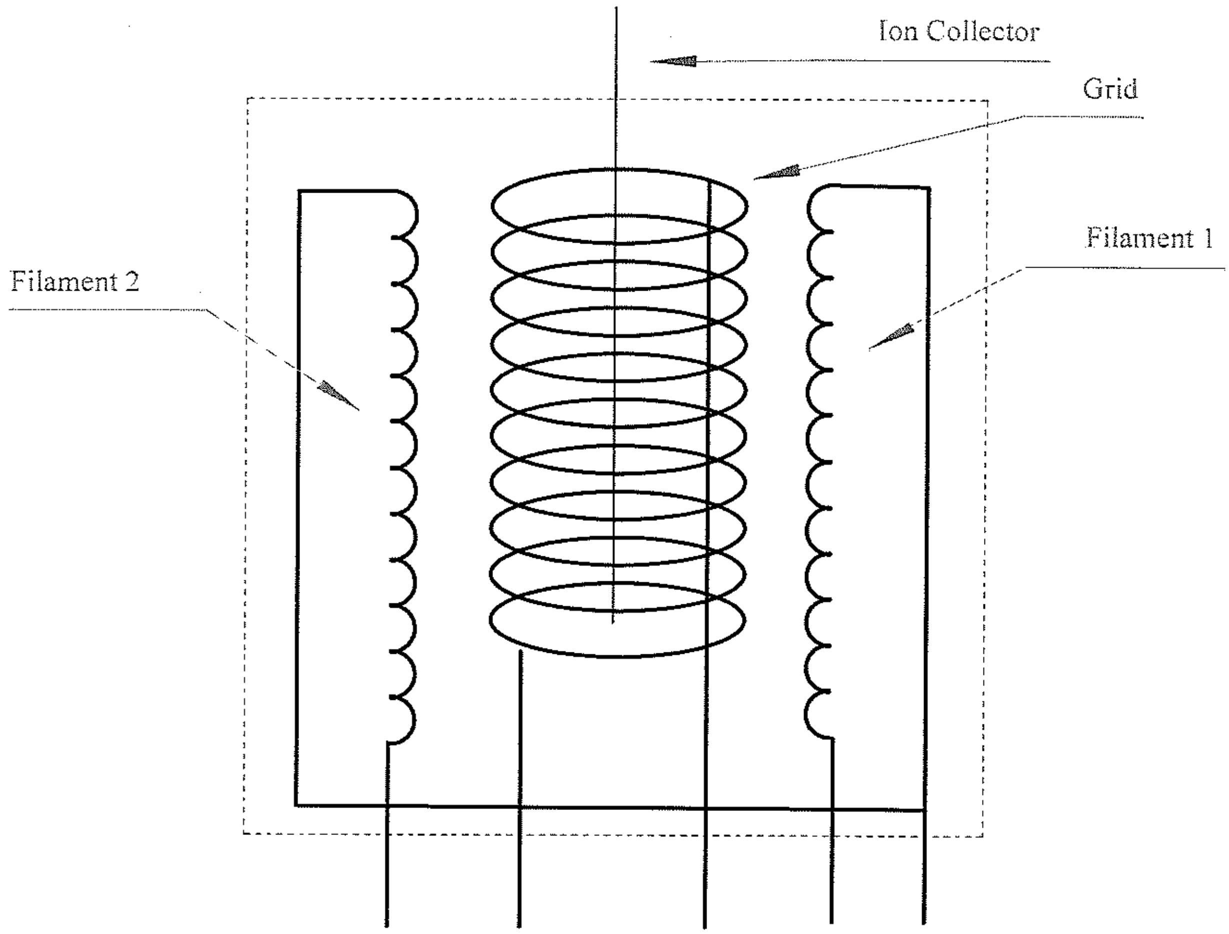


Figure 5

Schematic view of a Bayard-Alpert Ion Gauge Tube

Note: Do not use as reference for connecting IG2200 cable to tube

Effects of Various Gases
(Relative Sensitivity)

We want to examine what effects different gases in the gauge tube will have on the indicated pressure. We have to make the distinction between the true pressure in the gauge tube and the pressure that is indicated by the controller. Almost all manufacturers calibrate their gauges so that the indicated pressure is nearly identical with the true pressure when the gas is a normal air mixture.

In any gauge tube that has a fixed volume and operates at a constant temperature, the true pressure is determined solely by the number of gas molecules present. However the indicated pressure in an ionization gauge is determined by the rate at which gas ions are collected. Typically this rate of collection is determined by the rate gas molecules are ionized. This ionization rate varies with gases, other than normal air or nitrogen, causing a discrepancy between the indicated pressure and the true pressure (when nitrogen or normal air is not being used). The relative sensitivity of a gas is the relationship between the ionization rate of the gas and nitrogen. When not using nitrogen, the indicated pressure of the ion gauge controller must be divided by the relative sensitivity number for that gas. Table 2 shows the relative sensitivities for various gases.

Gas Type	Relative Gas Sensitivity S/SN	IG2200 Adjustment
Helium	0.178	02
Neon	0.316	03
Hydrogen	0.410	04
Oxygen	0.780	08
Water Vapor	0.90	09
Nitrogen	1.00	10
Carbon Monoxide	1.01	10
Carbon Dioxide	1.39	14
Argon	1.42	14
Krypton	1.94	19
Xenon	2.75	28

Table 2

Degas

There is a possibility at some time during ion gauge operation that the pressure in the gauge tube will be higher than the pressure in the vacuum system because of gases and vapors desorbing from the surfaces of the gauge tube. Degassing is the process by which we attempt to speed up desorbtion or outgassing of the surfaces inside the gauge tube. Once these surfaces are outgassed or degassed, the pressure in the gauge tube is more likely to be equal to the pressure in the vacuum system.

Remote Operation (RS-232)

The IG2200 Ion Gauge Controller has a full functioning Remote computer port. All aspects of the IG2200 can be controlled via the RS-232 interface by sending simple commands to the controller. Any computer or terminal with a serial RS-232 port can be connected to the IG2200. If the controller is connected when the power is turned on the Software version name will be sent to the computer.

RS-232 Interface

The RS-232 interface uses a standard 9 pin serial port. The port specifications are listed in table 3 below. The Pin out of the controllers RS-232 port is listed in table 4, you can get by with only the TX, RX & Ground wires connected. The DTR is connected internally to the DSR and the RTS to the CTS.

Interface Type	RS-232
Interface Mode	DTE
Baud Rate	2400
Stop Bits	1
Data Bits	8
Parity Bits	None
Flow Control	None
Voltage of Logic 0	+12 VDC
Voltage of Logic 1	-12 VDC

Table 3

Pin	Function
1	NC
2	TX (Transmit Data)
3	RX (Receive Data)
4	DTR
5	Ground
6	DSR
7	RTS
8	CTS
9	NC

Table 4

Command	Response	Example	Description
=SF1	F=:On	=SF1 F=On	Turn On Ion Gauge (you should check the status to see if the filament stays on or gets shut off)
=SF0	F=Off	=SF0 F=Off	Turn Off Ion Gauge
=SD1	D=On	=SD1 D=On	Turn On Degas (you will get an Error 3 if the Ion gauge is not on)
=SD0	D=Off	=SD0 D=Off	Turn Off Degas
	Error 1	sdkcjbn Error 1	Syntax Error
	Error 2	=ST:99 Error 2	Number Out of Range
	Error 3	=SD1 Error 3	Operation Not Allowed
	Error 4		Tx Buffer Overflowed

Advanced Commands

=R#	IGS300 V?.??.?? SN: <serial number>	=R# IGS300 V1.01.00 SN:J92S101-023	Read Serial Number
=X	IGS300 V?.??.??	=X IGS300 V1.01.00	Reset IG2200 (Displays Software Version)

JC CONTROLS
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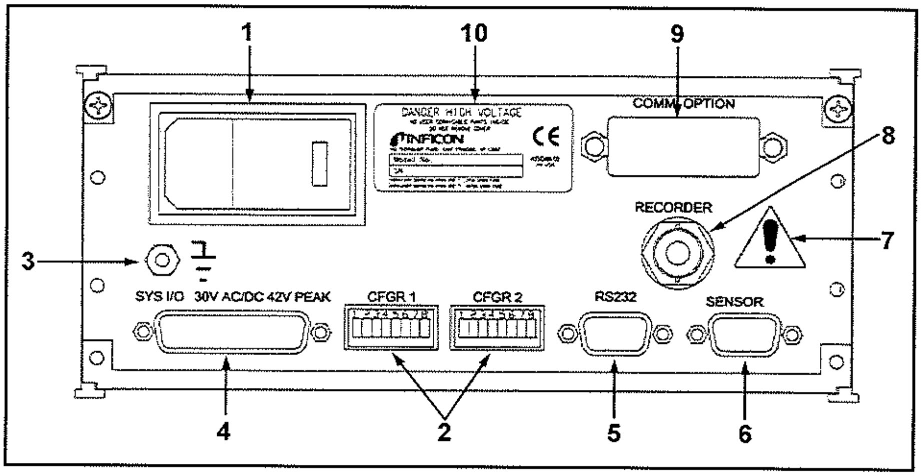
WEB SITE: www.jccontrols.net E-MAIL: sales@jccontrols.net

2.5 XTM/2 Rear Panel Description

The rear panel provides the interface for all external connections to the instrument. Each ballooned item is covered in the following respectively numbered sub-paragraphs.

Figure 2-8 XTM/2 Rear Panel



3.7.2 Inputs

Inputs are activated by pulling the specific input's terminal to ground (<0.8V) through a contact closure to common (GND) or with TTL/CMOS logic having current sink capability of 2 ma (1 low power TTL load). These ports are read every 250 ms; signals must be present during a read cycle.

Table 3-4 System I/O Connector

Pin #	Function	Description	Input #
14,15,16,17	Input Common (GND)	Used as reference for activating any of the inputs	
18	**OPEN**	Detection of a falling edge duplicates front panel OPEN	1
19	**CLOSE**	Detection of a falling edge duplicates front panel CLOSE	2
9	**CRYSTAL FAIL INHIBIT**	Presence of a closure to ground reference prohibits the closure of the Crystal Fail Relay.	3
20	**ZERO** thickness	Detection of a falling edge duplicates the front panel ZERO, for thickness only.	4
21	**ZERO** timer	Detection of a falling edge duplicates the front panel ZERO for the timer only.	5

3.7.3 Chart Recorder

The chart recorder output has 12 bit resolution with one additional bit of sign information over the range of -10 to +10 volts. It can supply up to 5 milliamps and has an internal resistance of 100 ohms. The output is proportional to rate, thickness or rate deviation depending on the setting of the configuration switches; see section 2.5.2 on page 2-15. It is normal for ripple to appear on these outputs to a maximum of 5 mV at ~84 Hz. This output is updated every 250 milliseconds.

3.8.1.1 IEEE Settings for a National Instruments IEEE-GPIB Board

When establishing IEEE communications the following settings are found to work using a National Instruments IEEE-GPIB board. These values are set using the IBCONF.EXE file provided by National Instruments.

Figure 3-6 Board Characteristics

National Instruments	Board Characteristics	IBM AT, PS/2-25/30
Board: GPIB0		SELECT (use right/left arrow keys):
Primary GPIB Address ↔	0	0 to 30
Secondary GPIB Address..........	NONE	
Timeout setting..................	T300ms	
EOS byte.........................	0AH	
Terminate Read on EOS............	yes	
Set EOI with EOS on Write.........	yes	
Type of compare on EOS	7-bit	
Set EOI w/last byte of Write	yes	
System Controller	yes	
Repeat addressing..................	no	
Disable Auto Serial Polling	yes	
High-speed timing..................	no	
Interrupt setting	7	
Base I/O Address..................	2C0H	
DMA channel (Arbitration)...........	5	
F1: Help	F2: Explain Field	F6: Reset Value F9: Return to Map

Figure 3-7 Device Characteristics

National Instruments	Device Characteristics	IBM AT, PS/2-25/30
Board: XTM2	Access: GPIB0	SELECT (use right/left arrow keys):
Primary GPIB Address ↔	3	0 to 30
Secondary GPIB Address..........	NONE	
Timeout setting..................	T300ms	
EOS byte.........................	0AH	
Terminate Read on EOS............	yes	
Set EOI with EOS on Write.........	yes	
Type of compare on EOS	7-bit	
Set EOI w/last byte of Write	no	
F1: Help	F2: Explain Field	F6: Reset Value F9: Return to Map

IEEE488 FORMAT (Message Protocol)

To XTM/2:	message_string LF d10 (CHR$10)	
From XTM/2:	message_string LF	(if success)
	- or -	
	error_code LF	(if failure)

SECS FORMAT (Message Protocol)

To XTM/2:	NN SECS_10_BYTE_HEADER message CS CS
From XTM/2:	NN SECS_10_BYTE_HEADER ACK message CS CS (if success)
	- or -
	NN SECS_10_BYTE_HEADER NAK error_code CS CS (if not)

If there is a problem, the unit will return a **NAK** preceded by one of the following Error Codes:

A. . . . . . . Illegal command

B. . . . . . . Illegal Value

C . . . . . . Illegal ID

D . . . . . . Illegal command format

E. . . . . . . No data to retrieve

F. . . . . . . Cannot change value now

G . . . . . . Bad checksum

NOTE: When transmitting commands directly by typing on a keyboard, the entire command, including the "ACK", must be entered quickly. Otherwise, the instrument will fail to recognize the transmission as a valid command.

3.8.4 Datalogging

Data logging may be configured to be automatic, see section 3.8.1 on page 3-16. The RS232 port is then configured to output the DATALOG information only and cannot receive commands from a host computer. The IEEE option, if installed, will continue to work in the normal fashion.

The Datalog data output represents the information concerning the latest **SHUTTER OPEN** to **SHUTTER CLOSE** sequence. The data is a series of ASCII strings, each separated by a carriage return (CR) and line feed (LF), in the order below:

1 Film #

2 Rate = _ _ _._ _Å/s [or ngm/sec or µgm/sec] [Last good rate if crystal failed]

3 Thickness = _ _ _ _._ _ _ _ kÅ [or µgm or mgm] [Last good thickness if crystal failed]

4 Deposit Time = _ _:_ _ Min:Sec.

5 Begin Frequency = _ _ _ _ _ _ _._ Hz

6 End Frequency = _ _ _ _ _ _ _._ Hz [negative of last good frequency if crystal fail]

7 Crystal Life = _ _%

In addition to automatic datalogging, the datalog information string is available via execution of the **S**12 communications command, or may be manually initiated by pressing the **CLOSE** (shutter) key on the front panel.

IPN 074-186S

3.8.5.4 Update Command

The format of the update command is:

U P F vvv.

Update parameter **P** of film **F**, with value vvv. A space is used as a delimiter between the **P** and **F** values as well as the **F** and vvv values, where **F** is a digit between 1 and 9;inclusive. Refer to Table 4-2 on page 4-4 for a numbered list of parameters and their limits.

or

U 6 F

Set the current film number to film **F**

See Query Command Parameter Definition Table for numbered list of parameters.

NOTE: The command "**U 99 F** Tooling Final Thickness SPT Thickness Density Z-ratio SPT Time" will update all parameters for film F. All parameter values must be separated by spaces and must use allowed values per those shown in the Parameter Definition Table.

3.8.5.5 Status Command

Sends back information based on specific request made.

The format of the status command is:

S xx . . . . Return the status (value) of xx

where:

S. . . . . . . Is the literal S

xx . . . . . . One or two digit code per list below:

S 0 . . . . . Rate, Thickness, Time, Xtal-Life

S 1 . . . . . Rate

S 2 . . . . . Thickness

S 3 . . . . . Time

S 4 . . . . . Film

S 5 . . . . . Crystal life (%)

S 10 . . . . Present configuration switch settings—returns 16 ASCII bytes with a value of 0 or 1, corresponding to the position of switches 1-16. Byte 1 corresponds to switch 1. See **S**13 also.

S10 Response Strings

Byte	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

[1 = switch on, refer to section 2.5.2 on page 2-15]

S 11 . . . . Power-up errors

S11 Response Codes

0. . . . Parameter data checksum error—indicates a loss of stored parameter data.

1. . . . STBY/ON sequence since last query—the front panel power switch has been used since the last inquiry.

2. . . . Line power failure.

9. . . . Process data checksum error—indicates a loss of process data.

10. . . No errors.

NOTE: If more than 1 error condition exists, the response string will list them all, each separated by a single space.

NOTE: STBY/ON status is cleared automatically by issuing an **S**11 command. All others require intentional clearing (available via remote command).

S 12 . . . . Datalog output, see section 3.8.4 on page 3-21. The data is separated by a space instead of CR LF.

S 13 . . . . Instrument Configuration, the position of the configuration switches at the last **STBY/ON** sequence. Use this command to determine the instrument's current operating configuration. See **S**10 also.