Automatic Pressure Controller using microcontroller

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ABSTRACT:
The constant total gas pressure require in many industrial application of Vacuum technology such as ion etching, coating, material processing etc. The constant total pressure also require during wall conditioning of the Tokomak vacuum vessel wall to control impurity in high temperature plasma experiment such as GDC, PDC, ECR. For these processes the working gas is introduced in the chamber using gas feed valve and the required gas pressure is maintained by adjusting the gas flow from this gas feed valve. The total gas pressure in the process chamber can vary due to many reasons like desorption of gases during the process, the change of gas flow from the gas feed valve, change in the pumping speed etc. To maintain the constant total gas pressure in side the vacuum vessel, we have developed AUTOMATIC PRESSURE CONTROLLER (APC) using fast response piezo electric gas leave valve and closed loop feedback control unit.
APC is an electronic circuit designed to maintain constant gas pressure in a process chamber. Pressure control is accomplished by continuously admitting the correct quantity of gas into a dynamic system to compensate for the variation in the quantity of the gas being removed or introduced in the system during the process. We had designed the APC in 1994 based on operational amplifier [1]. Now we have made some modification and used microcontroller. This paper will describe about it.

Keyword: piezo electric valve, ionization gauge, turbo-molecular pump, micro-controller

1. INTRODUCTION:

There are many industrial applications of vacuum technology such as sputtering,
coating, ion etching, material processing etc; which require constant total gas
pressure in process chamber. The constant total gas pressure also require during Glow Discharge Cleaning (GDC), Pulse Discharge Cleaning (PDC) and Electron Cyclotron Resonance Discharge Cleaning (ECRDC), conditioning of TOKAMAK vacuum vessel wall for impurity control in high temperature plasma experiments.
At present PDC and ECRDC is regularly employed on tokamak ADITYA for wall conditioning and it is necessary to maintain total gas pressure at set level of about $3.0*10^{-5}$ torr during this process for optimum result.
The APC can be used for slow as well as fast control of the gas. The APC uses electrically operated gas feed valve such as piezo electric valve to adjust the gas flow rate to control the pressure inside the process chambers. The main components required for apc are (a) Pressure monitoring system (b) Feed back control system and (c) electrically operated gas leak valve.

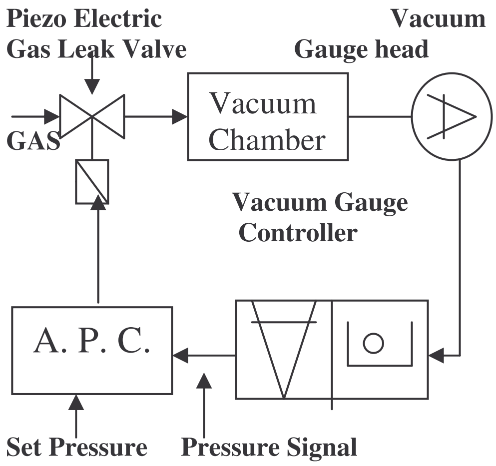


Figure 1:Layout of main components of Automatic Pressure Controller

2. CLOSED LOOP PROCESS CONTROL:

The Schematic of the main components required for automatic pressure control in process chamber is shown in the fig. 1[1]. The ultimate pressure in vacuum chamber will determine by the gas load from the gas leak valve as well as other sources and the pumping speed. The pressure inside the vacuum chamber is monitored using a vacuum gauge during the process. The vacuum gauge gives analog voltage output corresponding to the pressure inside the vacuum chamber. This voltage signal of pressure is used as the feedback signal in the APC circuit and it is compared with the voltage level set for the required pressure in the system. The error signal is generated by this comparison and microcontroller gives the corresponding correction voltage is applied to the gas leak valve. Thus, the pressure control is accomplished by automatically and continuously admitting the controlled quantity of gas to a dynamic system. The response of the APC depends upon the response of the vacuum gauge and piezo electric valve.
In APC design presented here, we have used piezo electric gas leak valve (Model PV 10,Make – Veeco Inc and Model MV 112,Make – Maxtek Inc.) for gas feed due to its fast response and reproducibility & B - A type ionization gauge (L – H make model 210D as it can measure pressure from 1x 10^{-2} torr to 1x 10^{-9} torr and provide electrical signals 0 to 10V DC corresponding to pressure value and 3 to 9V DC corresponding to pressure index.

3. BLOCK DIAGRAM AND DESCRIPTION.

The two inputs from ion gauge controller corresponding to pressure value (PV) and pressure index (PI) are processed as shown in the block diagram fig. 2, before applying as actual value to the one channel of ADC0809 e.g. let pressure inside the vacuum chamber is 2.0 x 10^{-7} torr.
Here PI = 7 VOLT & PV = 2 VOLT
Therefore, the o/p of the second block is

V1 = (7 – (2/10))/2 = 3.4 volt
This o/p is then applied to channel 0 of ADC0809.
The desired pressure in the vacuum chamber is set by two potentiometer provided on the front panel of the unit

Here out of two potentiometer, one is to set pressure value and the another is to set pressure index. The two inputs from these potentiometers are processed as shown in the block diagram fig. 2. The output from this block is

V2= (PI- (PV/10))/2

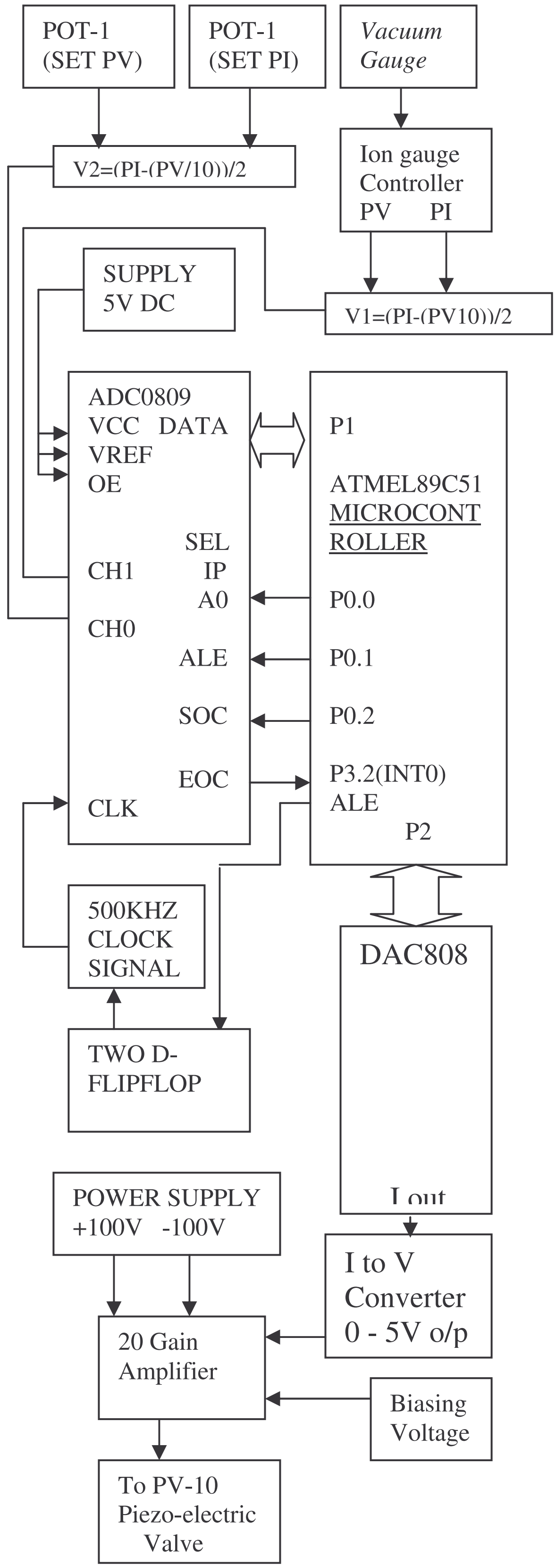
This o/p is then applied to channel 1 of the ADC0809.
So, in this way the input two the channel 1 is set manually which is nothing but reference value.

3.1 ANALOG TO DIGITAL CONVERTER:

We have used IC ADC0809 for A to D conversion, which converts the analog signal given to its input into a digital signal, which is fed to Micro-controller. This ADC contains 8 input channels out of which we are using 2 input channels i.e. CH0 and CH1, while other channels are grounded.

The output pins D0 to D7 of the ADC is connected to port1 of Microcontroller 89C51. The channel selection pin A0 is connected to the pin p0.0 of Microcontroller, which can be set or reset as per our requirement by the program to select either of the two channels (CH0 & CH1). When channel CH1 is selected, the feedback signal (actual voltage value corresponding to the pressure inside the vacuum chamber) is converted from analog to digital and fed to Microcontroller, where as channel CH0 is connected to variable voltage, constant current circuit to set the reference voltage corresponding to the desired value of pressure.
The Microcontroller is the heart of the feedback control system. Here Microcontroller get the two digitized values from ADC0809 corresponding to the actual pressure value and set pressure valve. Based on these two values, each time microcontroller compare theses values and send some data to digital to analog converter (DAC808). The output pin of the DAC is connected with the operational amplifier. This converts it in to analog voltage. Which is further amplified by 20 gain amplifier. A bias voltage of 1 volt is also applied to 20 gain amplifier. The output of the 20 gain amplifier is given to piezo electric gas leak valve. Throughput of the piezo electric gas leak valve depends upon the voltage applied on it. In this way the pressure inside the chamber, vary. And the ion gauge gives changed voltage signal corresponding to the changed pressure inside the chamber. When both actual and reference signal become equal, voltage to the piezo electric leak valve did not change. Thus piezo electric valve maintain the pressure inside the chamber.
Here initially the vacuum chamber is pumped down to 5 x 10^{-8} torr, so the value of pressure index (in this case 8V) always remains high initially and so the input to the channel 0 which is given by

(PI – PV/10)/2 = (8 – 5/10)/2 = 3.75v



BLOCK DIAGRAM OF APC
Figure-2

Lets our desired pressure is 5 x 10^{-4} torr, which gives input voltage at channel 1 as given by

(PI – PV/10)/2 = (4 – 5/10)/2 = 1.75v

Initially, always this value is less than the actual value. Now when the actual voltage at the channel 0 of ADC0809 is greater than the reference value at the channel 1 of ADC0809 (which is the initial condition of the system), the voltage to the gas leak valve is increased from 0v step by step after each comparison. The valve start to open and let the gas goes inside the chamber, which increases the pressure inside the chamber gradually by small increment in the valve opening after each comparison. When the desired pressure
inside the chamber comes the actual value read by the ADC0809 matches with the
reference value and the controller stop the increment of the opening of the valve and the pressure is maintained at that value which is desired pressure. Meanwhile if the pressure increases from the desired value then the condition of the comparison is reversed and the Microcontroller senses the actual value less than the reference value and controller starts to decrement the valve voltage gradually. In this way controller, keep it self busy in marinating the actual.

4. TESTING OF APC:

Fig. 3 shows the schematic of the vacuum system used for the testing of the APC. A turbo-molecular pump of 500 ltr/sec pumping speed is connected to UHV chamber of about 5 liters volume giving about 300 ltr/sec net pumping speed at the chamber. A B/A type L-H make IG, Piezo electric gas leak valve (PV-10) and manual gas leak valve with micrometer screw are mounted on the chamber.

4.1 Testing procedure and results:

The testing procedure of APC involves the simulation of real gas load variation, monitoring of system pressure and monitoring of the change in the applied voltage to the piezo electric gas feed valve. This described in the following sections.

4.2 Gas Load Calibration:

To check the performance of APC, it is essential to simulate the variable gas load using manual gas leak valve. For this the micrometer screw position of manual leak valve was calibrated in terms of gas throughput as follows.
The power to the APC was switched off initially, the manual gas leak valve was opened slowly, and air was admitted in the vacuum chamber. For each position of the micrometer screw of the manual leak valve the system pressure was monitored and knowing the pumping speed (300 ltr/sec) of turbo molecular pump gas throughput was calculated. This was repeated for number of times and average valve of gas throughput for various micrometer positions of manual leak valve was find out.

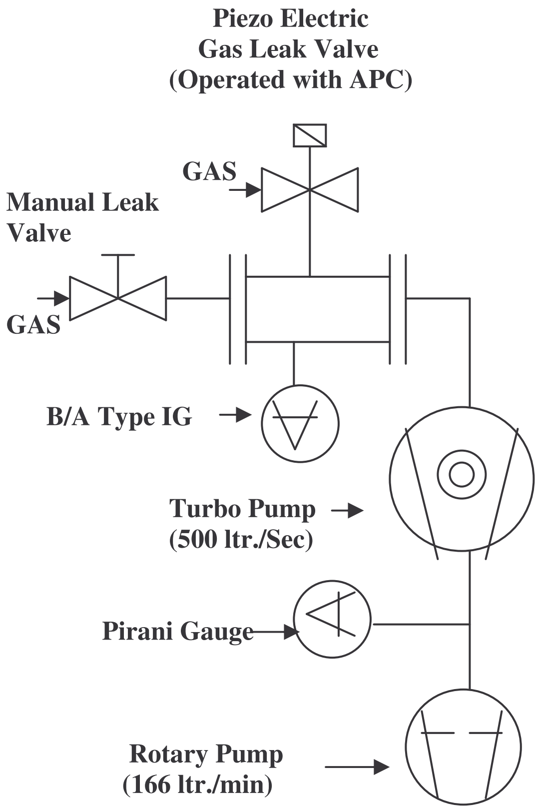


Figure 3: Vacuum System for APC Testing.

4.3 Testing with PV 10 Gas feed Valve:

Initially the vacuum chamber was pumped down to 1x10^{-7} torr, and the air was admitted in the chamber using manual gas leak valve and the system pressure was increased to 1x10^{-6} torr. Thus, initially the constant gas load of about 3x10^{-4} torr ltr/sec was adjusted in the system. The o/p of APC was connected to PV-10 gas feed valve. The system pressure was set by potentiometer at 3.0x10^{-5} torr. As, we switched on APC. It set the said system pressure within one minute. The voltage on the PV-10 valve and the system pressure were recorded. After this, the gas load in the system was gradually increased using manual leak valve and the system pressure as well as the voltage on the PV-10 valve were monitored. Fig. 4 shows the system pressure as well as the in the valve voltage required to control this pressure with varying gas load to the system. It can be seen that pressure in the system is constant for the gas load varying from 3x10^{-4} torr ltr/sec to 2x10^{-2} torr ltr/sec. At this valve of the gas load the PV-10 valve, voltage reduced to about 20 volts were it got completely closed. After this the system pressure was basically decided by the gas load from the manual leak valve and hence it started increasing as can see in the fig. 4.

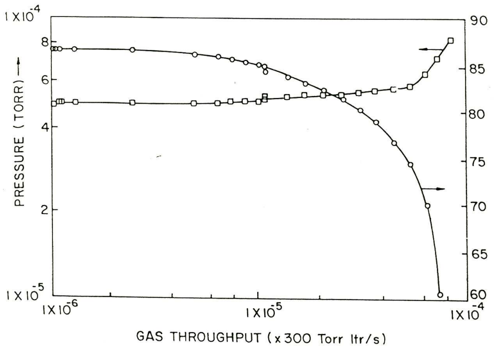


Figure 4: Performance of APC with PV-10 Valve

This APC using microcontroller is being successfully tested in the test stand and will now be used with Aditya Tokamak during ECR and PDC discharge cleaning.

[1] M. S. Khan, H. A. Pathak, H. D. Pujara, S. B. Bhatt & Y. C. Saxena " Design of Automatic Pressure Controller" Technical Report, IPR, IPR/TR-51/94, March 1994.