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ELECTRONIC PRESSURE REGULATOR

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ABSTRACT

Pneumatic pressure regulators are used for varying the pneumatic pressure from the air reservoir to the actuator. The pressure regulator has a knob which needs to be rotated for varying the output pressure. However, the system cannot maintain a constant pressure after the actuation of the pneumatic cylinders. The manually operated regulator is another shortcoming of the system. This paper focuses on automation of the mechanical pressure regulator where it can be controlled directly by electronic signals and further operated remotely from control station. This automated system, named as electronic pressure regulator has a motor with servo mechanism for rotating the pressure control knob. A digital pressure sensor is used to obtain the actual pressure of the system which in turn feeds the error value to the PID algorithm.

Keywords: *Pneumatic Pressure Regulator, Servo mechanism, PID control, LM629, Regulator, Automation.*

I. INTRODUCTION

The project is to design an Electronic Pressure Regulator (EPR) to control the pneumatic air pressure in the system. The main purpose of this system is to build an electronic regulator that gives us the ability to control the air pressure using electrical signals to a precision value. This system consists of mechanical pressure regulator precisely controlled by a motor attached to it. The circuit developed must be able to set the pressure and feedback needs to be taken from the pressure sensor to check whether an error has occurred in the actual and update pressure. The board should be compact so that it can be mounted in the machines easily.

It is difficult to maintain the pressure in system and moreover varying the pressure is thus more difficult. Using the sensor to read the pressure in the system and then maintaining the pressure was the most important task. Also, the system must be compact and self -contained in the sense it must have an on-board battery pack.

With recent advances in the pneumatics system, the pressure regulation and variation are the major scope where most of the Industries are working on. Knowing that the power delivered by pneumatics system is quite high, this has been an emerging sector. Using a basic microcontroller (Atmega 16) serves the purpose of controlling a motor and tracking the feedback system.

The aim of this project is the use of dedicated motion-control controllers/ICs designed for use with a wide range of DC and brushless DC servo motors, and other servomechanisms which provide a quadrature incremental position feedback signal. This processor use PID algorithm (Proportional Integral Derivative) to control motion of motor. The pressure feedback loop uses the same mentioned algorithm. This makes the system fast and error-free**.**

II. LITERATURE REVIEW

Pneumatic pressure regulator has the advantages, such as small size, convenience in assembly. For solenoid valves to be a pilot level proportional pressure valves, the system comprises of a main valve, a pilot control valve, a digital controller, and a pressure sensor. Fig. 1 is an electric proportional valve of FESTO Company.

Massimo Sorli has conducted an extensive research on electromagnetic proportional valve. Based on relationship of the internal components of the valve, a nonlinear mathematical model is established, and the dynamic behavior

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of the valve is studied. Massimo Sorli discovered that when the output pressure of the pressure reducing valve reaches the preset pressure, the two switches in the control chamber will remain closed and thus there is lesser energy consumption. However, when the preset pressure changes, it needs to adjust the control valve in the cavity to control the pressure in the valve cavity, frequent opening and closing, and the slow response of the valve, which causes the output frequency response of low pressure value. Switch electromagnetic pneumatic pressure proportional valve has an advantage of low energy, compact and simple structure and static pressure regulation. However, it is insensitive to the rapidly changing pressure signal due to low frequency response. The pressure loss in the chamber is also large which affects the efficiency at which the pneumatic pressure from the reservoir is utilized.

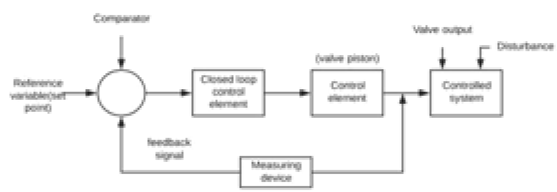

Fig. 1. Festo MPPE proportional valve working principle diagram

III. FUNCTIONAL BLOCK DIAGRAM AND INTERFACING DETAILS.

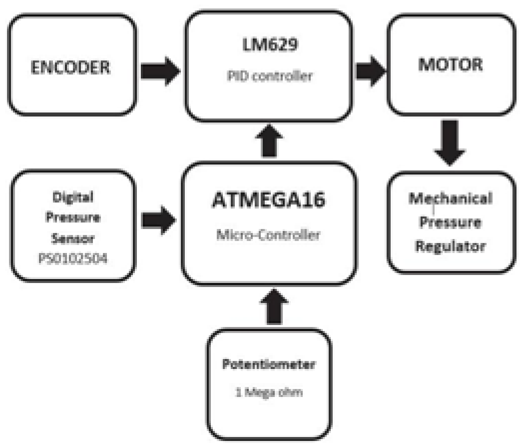

Fig. 2. Block diagram of system

Fig. 2 shows the block diagram of the Electronic Pressure Regulator.

The system consists of 4 main sub-systems: -

i. Power Circuit
ii. LM629
iii. Main Board with Atmega 16 Microcontroller
iv. Digital Pressure Sensor
v. Motor with Encoder and Motor driver.
vi. Mechanical Pressure Regulator
vii. Potentiometer

A. Power Circuit Unit

The Power Circuit Unit supplies required (5V) voltage to main microcontroller and interfaced circuitry. Power Circuit contains the Voltage Regulator IC 7805 which converts 12V to 5V. A 12V lithium polymer battery is the input to the power circuit unit. The voltage regulator supplies a maximum of 1A, which is sufficient for the application.

B. PID motion controller LM629

The LM629 is a dedicated motion control processor designed for use with a variety of DC motors which provides a quadrature incremental position feedback signal. Using the LM629 co-processor a servo mechanism can be implemented using any dc motor with encoder and a motor driver [3].

C. Main board with microcontroller

Main Board with Atmega16 Microcontroller controls the pressure of the system with the help of precise movement of DC motor. A feedback loop LM629 IC is interfaced and controlled by the signals of controller [2][8].

D. Digital Pressure Sensor (PS0102504)

The digital Pressure Sensor is a transducer which converts the pneumatic pressure into an equivalent digital voltage signal. The Pressure Sensor provided the output in the form of an analog signal proportional to the present pneumatic pressure of the system [9].

E. DC Motor Driver Module (VNH5019A)

Dc motor with encoder is used to move shaft of mechanical pressure regulator to adjust the pressure. Microcontroller is interfaced with the Motor Driver Module to operate the Motors. Motor driver Module is given with the PWM by the Microcontroller to vary the speeds/rpm of the Motor. Outputs of the Motor Drivers are connected to the Motor Connectors.

IV. ALGORITHM AND CALCULATIONS

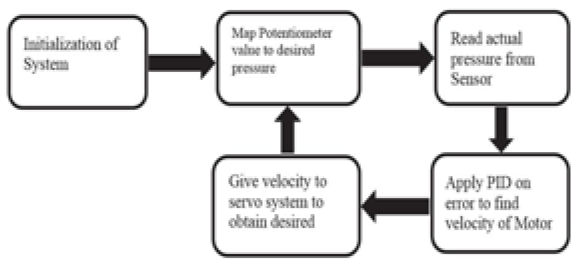

Fig. 3. Flowchart of Pneumatic Pressure Control.

A. Algorithm

i. Initialization of Main micro controller ATMEGA16:

- The main microcontroller ATMEGA16’s input/output pin initialization.
- Initialization of timer of ATMEGA16 to generate 4MHz clock provided to LM629 IC.
- ADC port of ATMEGA16 initialized to take potentiometer Analog reading.
- Serial port of ATMEGA16 initialized for communication.

ii. Initialization of PID Controller LM629:

- Hardware resets to IC.
- Upload filter parameter (P, I, D) values.
- Load desired acceleration value in degrees/(Sec)2 and zero velocity in degree/Sec for start.

iii. Take Analog value of potentiometer and Map Analog value to corresponding pressure between 0-2500 (barx1000). Pass desired pressure to pressure regulator system [5].

iv. Read an Analog value of pressure sensor which gives you actual pressure of system. To convert Analog value in pressure in bar, the following formulas:

Pressure in bars(x1000) = Analog value – 230 (1)
Current Pressure in bar(x1000) = Pressure in bar(x1000)/0.106 (2)

v. Take difference of desired pressure and current pressure to find error.

Error = Desired Pressure – current Pressure (3)

vi. Apply PID algorithm on error generated in the previous step to find velocity required to move actuator (Motor attached to pressure regulator) using following Logic [1]:

Integral += error

if(Integral>40000)

Integral = 40000

else if(Integral”40000)

Integral = -40000

velocity = KP*error + KI*Integral + KD*(error-previous error)

previous error = error

vii. If velocity generated previous step is positive, Load LM629 with desired velocity in forward direction.
viii. Else velocity generated previous step is negative, Load LM629 with desired velocity in backward direction.

ix. LM629 has internal PID loop which will maintain given velocity using encoder attached to motor [6][7].
x. Repeat steps from 3 to 9 until desired pressure is achieved.

Calculations

i. Potentiometer:

- Potentiometer max resistance = 1M ohm
- ADC used in microcontroller: 10-bit ADC
- Resolution of ADC = 5/2^10 = 0.00488 V

The total ADC mapping for voltage range 0V to 5V is 0 to 1023

ii. System Pressure requirement:

- Minimum pressure: 0 bar
- Maximum pressure: 2.5 bar

Thus, the Max ADC count should correspond to Max

system tolerable pressure.
Therefore,
1 ADC count = (Max pressure * 1000)/Max ADC count (4)

iii. Pressure Sensor:

- Resolution of Pressure Sensor: 0.01bar
- Rated Pressure range: 0bar to 10 bar
- Analog Output: 1V to 5V +/- 2.5% tolerance

Here, 0bar pressure corresponds to 1V Whereas, 1V corresponds to 230 ADC counts Actual Pressure Measured using Pressure Sensor,

(Pressure *1000) = (ADC Value – 230)/0.106 (5)

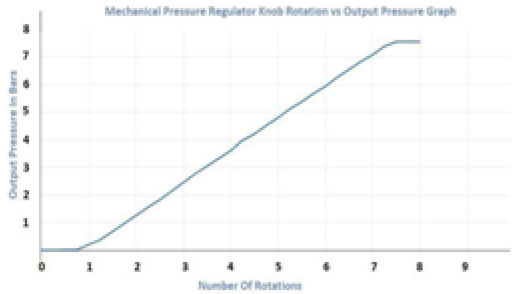

Fig. 4. Graph plot of number of rotations of pressure control knob vs change in output pressure

V. COST ANALYSIS

Sr. No.	Component	Quantity	Cost INR
1	Battery (LiPo 1000mAh)	2	1150
2	Atmega16	1	150
3	Connectors and Cables	-	100
4	Discrete Components	1	500
5	DC Geared Motor with inbuilt encoder	1	1500
6	Mechanical Materials	-	130
7	LM 629 IC	1	Free Sample
8	Pressure Sensor	1	Sponsored
9	Miscellaneous	-	100

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10	**Total**		**3530**

VI. CONCLUSION

The electronic controlled proportional pressure regulator was successfully designed and tested. The conclusions derived from the tests are as follows.

1. The electronic pressure regulator has an offset in the control of pressure.
2. The offset in pressure control was mainly due to error in the encoder counts due to slippage of gear attaching the motor-encoder assembly shaft and the mechanical pressure regulator.
3. This error was further minimized by using a motor with inbuilt encoder.
4. Once the pressure was set after every actuation of the pneumatic cylinder a certain adjust time was required for the feedback system to adjust the pressure to the desired pressure value.

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