DC Motor Speed Control using PID Algorithm through NI Labview and Low Cost AVR Micro-Controller.

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CERTIFICATE

This is to certify that the thesis entitled "***DC Motor Speed Control using PID Algorithm through NI Labview and Low Cost AVR Micro-Controller***" being submitted by ***Mr. Saket Adhau*** (**ID NO.13161001), *), Mr. Rushikesh Surwase*** **(ID NO.13161002*), Miss Sanheeta Deshkar*** **(ID NO.13161027*), Mr. Ramesh Padwal*** **(ID NO.13161051** to the Government College of Engineering and Research, Awasari, Pune for the award of the degree of **Bachelor of Engineering** in Instrumentation and Control Engineering is an authentic work carried out by them. They have worked under my guidance and supervision and has fulfilled the requirement for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted in part or full, to any other University or Institute for the award of any degree or diploma.

Date: April 3, 2017

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ABSTRACT

The present work shows the importance and one of the major application of the NI LabVIEW in the area of virtual instrumentation for academic purposes. The work also tries to reduce the cost of the NI DAQ card using a low cost 8 bit AVR microcontroller as a data acquisition device. The reduced cost makes labview accessible for basic undergraduate project works and college level lab practical and training purposes. The microcontroller communicates with the system through serial communication.

For the demo purpose, speed control of DC Motor using P-I-D controller is done using the created DAQ card and labview. Further to prove the advantages of the proposed work, the results of the PID algorithm implemented using microcontroller are compared with the results obtained by using the traditional NI DAQ cards.

Table of Contents

CHAPTER 1

1. INTRODUCTION

In this chapter, the overview of the different controllers are described. Literature survey of the work has been discussed. The objective of the thesis is explained. At the end organization of thesis has been presented.

1.1 INTRODUCTION TO LABVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench), a product of National Instruments, is a powerful software system that accommodates data acquisition, instrument control, data processing and data presentation. LabVIEW which can run on PC under Windows, Sun SPAR stations as well as on Apple Macintosh computers, uses graphical programming language (G language) departing from the traditional high level languages such as the C language, Pascal or Basic.

All LabVIEW graphical programs, called Virtual Instruments or simply VIs, contains a Front Panel and a Block Diagram. Front Panel has various controls and indicators while the Block Diagram consists of a variety of functions. The functions (icons) are wired inside the Block Diagram where the wires represent the flow of data. The execution of a VI is data dependant which means that a node inside the Block Diagram will execute only if the data is available at each input terminal of that node. By contrast, the execution of programs such as the C language program, follow the order in which the instructions are written.

LabVIEW manages data acquisition, analysis and presentation into one system. For acquiring data and controlling instruments, LabVIEW supports IEEE-488 (GPIB) and RS-232 protocols as well as other D/A and A/D and digital I/O interface boards. The Analysis Library offers the user a comprehensive array of resources for signal processing, statistical analysis, filtering, linear algebra and many others. LabVIEW also supports the TCP/IP protocol for exchanging data between the server and the client. LabVIEW v.5 also supports Active X Control allowing the user to control a Web Browser object.

The version used for our project is LabVIEW 2014.

Fig.1. Introduction to labview

1.2. DATA ACQUSITION USING LABVIEW

Data acquisition (DAQ) is the process of acquiring an electrical or physical phenomenon such as voltage, current, temperature, sounds or pressure with a computer. A DAQ system consists of a DAQ card or sensor, hardware from which data is to be acquired and a computer with associated software. A DAQ card has various features which can be designed for different purposes. For data involving very high accuracy the sampling rate of the card should be high enough to reconstruct the signal that appears in the computer. NI USB-6363 DAQ can be used to get data related to impulse voltage which require very high accuracy. Sampling rate of this card is 2MS/s (mega samples per second). This DAQ can be used in variety of platform like Microsoft windows, MAC, and Linux etc. For acquiring data from high voltage system, first the system parameters should be scaled down to values supported by the DAQ card. So the high voltage system should be connected to instrument transformer to scale down the voltage as well as current. For remote control of a system (standalone mode), Compact RIO can be used which provides embedded control as well as data acquisition system. The Compact RIO system's tough hardware configuration includes a reconfigurable field-programmable gate array (FPGA) chassis, Input/output modules, and an embedded controller. Additional feature of Compact RIO is, it can be programmed with NI LabVIEW virtual instrument and can be interfaced.

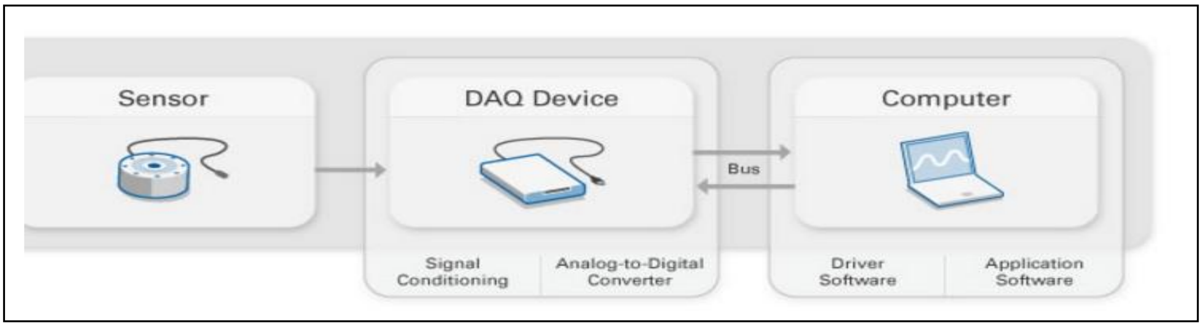


Fig.2. DAQ card

1.3 PID (PROPORTIONAL INTEGRAL DERIVATIVE)

1.3.1 P Controller:

P controller is mostly used in first order processes with single energy storage to stabilize the unstable process. The main usage of the P controller is to decrease the steady state error of the system. As the proportional gain factor K increases, the steady state error of the system decreases. However, despite the reduction, P control can never manage to eliminate the steady state error of the system. As we increase the proportional gain, it provides smaller amplitude and phase margin, faster dynamics satisfying wider frequency band and larger sensitivity to the noise. We can use this controller only when our system is tolerable to a constant steady state error. In addition, it can be easily concluded that applying P controller decreases the rise time and after a certain value of reduction on the steady state error, increasing K only leads to overshoot of the system response. P control also causes oscillation if sufficiently aggressive in the presence of lags and/or dead time. The more lags (higher order), the more problem it leads. Plus, it directly amplifies process noise.

1.3.2 P-I Controller:

P-I controller is mainly used to eliminate the steady state error resulting from P controller. However, in terms of the speed of the response and overall stability of the system, it has a negative impact. This controller is mostly used in areas where speed of the system is not an issue. Since P-I controller has no ability to predict the future errors of the system it cannot decrease the rise time and eliminate the oscillations. If applied, any amount of I guarantees set point overshoot.

1.3.3 P-I-D Controller:

P-I-D controller has the optimum control dynamics including zero steady state error, fast response (short rise time), no oscillations and higher stability. The necessity of using a derivative gain component in addition to the PI controller is to eliminate the overshoot and the oscillations occurring in the output response of the system. One of the main advantages of the P-I-D controller is that it can be used with higher order processes including more than single energy storage.

1.3.4 Loop Tuning:

Tuning a control loop is arranging the control parameters to their optimum values in order to obtain desired control response. At this point, stability is the main necessity, but beyond that, different systems leads to different behaviours and requirements and these might not be compatible with each other. In principle, P-I-D tuning seems completely easy, consisting of only 3 parameters, however, in practice; it is a difficult problem because the complex criteria at the P-I-D limit should be satisfied. P-I-D tuning is mostly a heuristic concept but existence of many objectives to be met such as short transient, high stability makes this process harder. For example sometimes, systems might have nonlinearity problem which means that while the parameters works properly for full load conditions, they might not work as effective for no load conditions. Also, if the P-I-D parameters are chosen wrong, control process input might be unstable, with or without oscillation; output diverges until it reaches to saturation or mechanical breakage.

For a system to operate properly, the output should be stable, and the process should not oscillate in any condition of set point or disturbance. However, for some cases bounded oscillation condition as a marginal stability can be accepted.

As an optimum behaviour, a process should satisfy the regulation and command breaking requirements. These two properties define how accurately a controlled variable reaches the desired values. The most important characteristics for command breaking are rise time and settling time. For some systems where overshoot is not acceptable, to achieve the optimum behaviour requires eliminating the overshoot completely and minimizing the dissipated power in order to reach a new set point.

In today's control engineering world, P-I-D is used over %95 of the control loops. Actually if there is control, there is P-I-D, in analog or digital forms. In order to achieve optimum solutions Kp, Ki and Kd gains are arranged according to the system characteristics. There are many tuning methods, but most common methods are as follows:

- **Manual Tuning Method**

Manual tuning is achieved by arranging the parameters according to the system response. Until the desired system response is obtained Ki, Kp and Kd are changed by observing system behaviour.

Although manual tuning method seems simple it requires a lot of time and experience.

- **Ziegler-Nichols Tuning Method**

More than six decades ago, P-I controllers were more widely used than P-I-D controllers. Despite the fact that P-I-D controller is faster and has no oscillation, it tends to be unstable in the condition of even small changes in the input set point or any disturbances to the process than P-I controllers. Ziegler-Nichols Method is one of the most effective methods that increase the usage of P-I-D controllers.

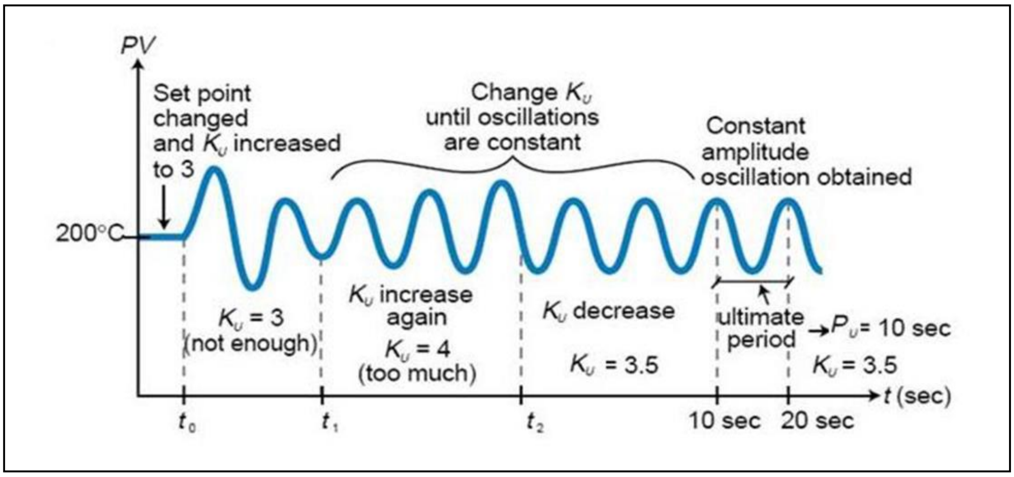


Fig.3.Ziegler-Nichols P-I-D controller tuning method.

The logic comes from the neutral heuristic principle. Firstly, it is checked that whether the desired proportional control gain is positive or negative. For this, step input is manually increased a little, if the steady state output increases as well it is positive, otherwise; it is negative. Then, Ki and Kd are set to zero and only Kp value is increased until it creates a periodic oscillation at the output response. This critical Kp value is attained to be "ultimate gain", Kc and the period where the oscillation occurs is named as Pc "ultimate period". As a result, the whole process depends on two variables and the other control parameters are calculated according to the table in the Figure 4.

Ziegler–Nichols method giving K' values (loop times considered to be constant and equal to dT)			
Control Type	Kp	Ki'	Kd'
P	0.50K_c	0	0
PI	0.45K_c	1.2K_pdT/ P_c	0
PID	0.60K_c	2K_pdT / P_c	K_pP_c / (8dT)

Fig.4. Ziegler-Nichols P-I-D controller tuning method, adjusting Kp, Ki and Kd

Advantages:

- It is an easy experiment; only need to change the P controller
- Includes dynamics of whole process, which gives a more accurate picture of how the system is behaving

Disadvantages:

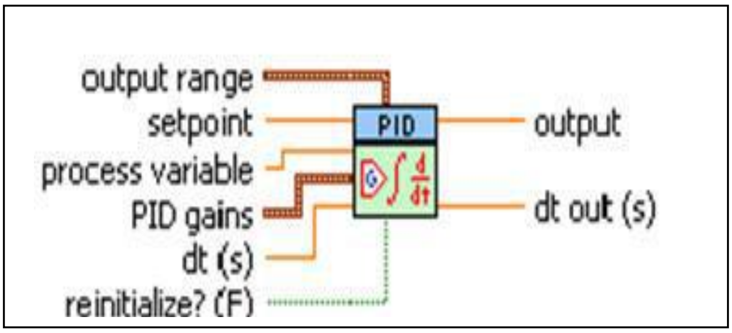
- Experiment can be time consuming
- It can venture into unstable regions while testing the P controller, which could cause the system to become out of control
- For some cases it might result in aggressive gain and overshoot.

- **Cohen-Coon Tuning Method.**
- **PID Tuning Software Methods (ex. LabVIEW & MATLAB).**

1.3.5. Digital P-I-D Control:

Digital P-I-D control is commonly used nowadays because of its ease of implementation. However, there are critical points that a designer should pay attention. Most critical step is the choice of the sampling period. Since the nature consists of analog signals, most plant transfer functions are modelled in continuous time. In order to implement a digital P-I-D controller the designer should take samples from the continuous time error signal. However, these samples should be taken frequently enough in order not to miss system dynamics.

Fig.5 PID



CHAPTER 2

2. DESIGN OF LOW COST DAQ CARD USING AVR MICROCONTROLLER.

2.1 Hardware of the system.

2.1.1 Microcontroller

The microcontroller is selected in such a way that it should fulfil basic operations like AD conversions, PWM, data acquisition and communication with the computer along with a reasonable price. Atmel's Atmega 328P which is an 8 bit microcontroller ensures all these functions with a flexible PDIP packaging for easy mounting. The microcontroller has on board ADC and 6 PWM channels with a power on reset circuit along with one serial interface for USART. The microcontroller needs a 5V DC source for its operation. Fig.6 shows the block diagram of the microcontroller used as a DAQ card.

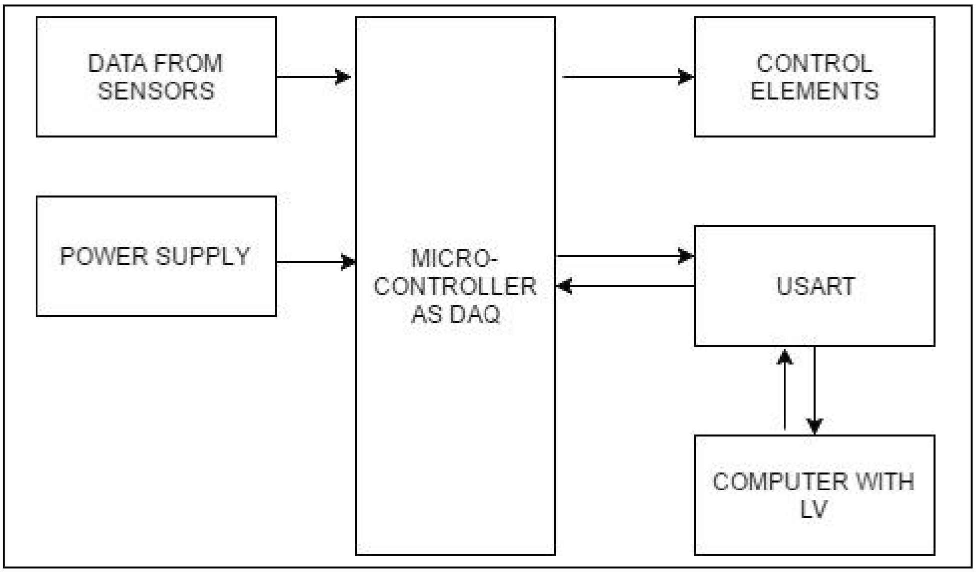


Fig.6. Block diagram of the microcontroller used as a DAQ card.

2.1.2 Features of the Microcontroller.

• Advanced RISC Architecture

– 131 Powerful Instructions

– Most Single Clock Cycle Execution

– 32 x 8 General Purpose Working Registers

– Fully Static Operation

– Up to 20 MIPS Throughput at 20MHz

– On-chip 2-cycle Multiplier

• High Endurance Non-volatile Memory Segments

– 32KBytes of In-System Self-Programmable Flash program

• Memory

– 1KBytes EEPROM

• Peripheral Features

– Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode

– One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode

– Real Time Counter with Separate Oscillator

– Six PWM Channels

– 8-channel 10-bit ADC in TQFP and QFN/MLF package

• Temperature Measurement

– 6-channel 10-bit ADC in PDIP Package

• Temperature Measurement

– Two Master/Slave SPI Serial Interface

– One Programmable Serial USART

– One Byte-oriented 2-wire Serial Interface (Philips I2C compatible)

– Programmable Watchdog Timer with Separate On-chip Oscillator

– One On-chip Analog Comparator

– Interrupt and Wake-up on Pin Change

• Special Microcontroller Features

– Power-on Reset and Programmable Brown-out Detection

– Internal Calibrated Oscillator

– External and Internal Interrupt Sources

– Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby

• I/O and Packages

– 23 Programmable I/O Lines

– 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF

• Operating Voltage:

– 1.8 - 5.5V

• Temperature Range:

– -40°C to 105°C

2.1.3 Pin Mapping of the Microcontroller:

The below image shows the basic pin mapping to be used while using the microcontroller.

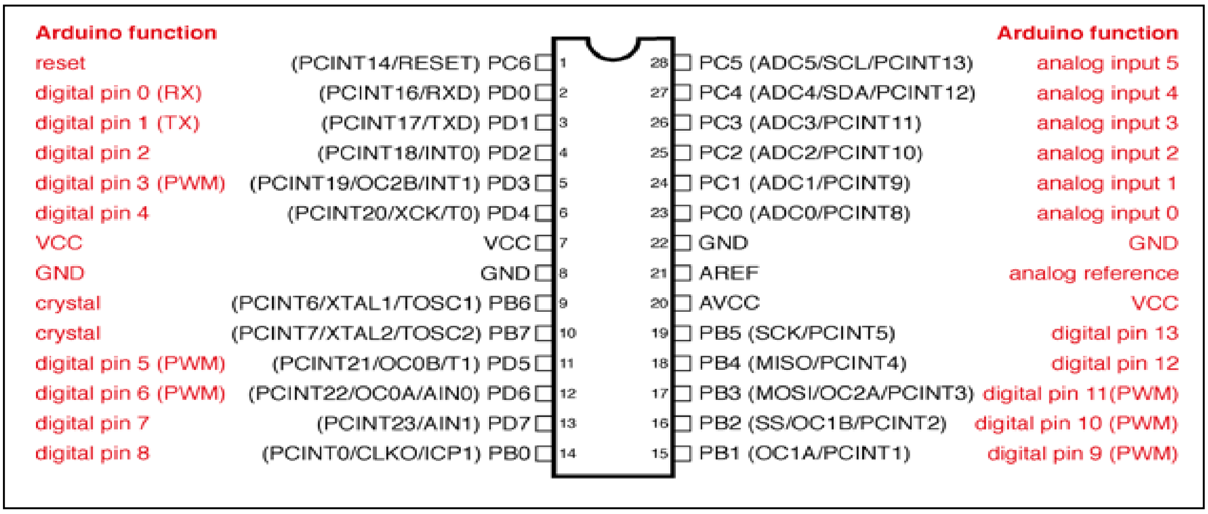


Fig.7. Pin Mapping

2.1.4 The low cost DAQ card.

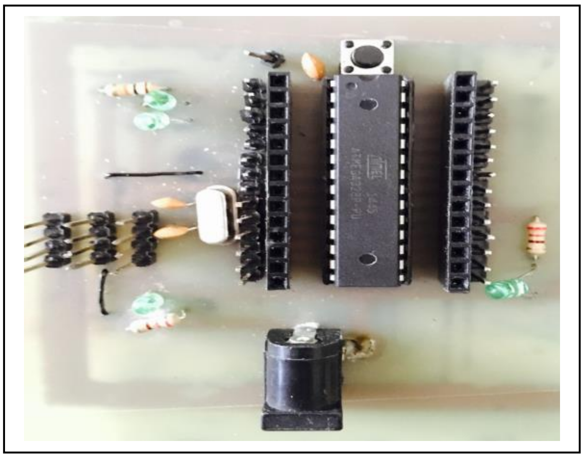


Fig.8. Manufactured Microcontroller DAQ card

CHAPTER 3

3. PID CONTROLLER DESIGN FOR CONTROLLING DC MOTOR SPEED IN THE PROJECT.

3.1 Why do we need to control the speed of DC motor?

For many cases, we cannot obtain the same desired results in terms of theoretical and practical cases. For that project, we have to make theoretical power calculations for DC motors to obtain the desired DC motor speed. However in practice, we could not obtain the same results as it is calculated theoretically. For that purpose we have to use controllers to minimize the error between actual and theoretical results.

3.2 Why to choose P-I-D as controller?

The aim in using the P-I-D controller is to make the actual motor speed match the desired motor speed. P-I-D algorithm will calculate necessary power changes to get the actual speed. This creates a cycle where the motor' speed is constantly being checked against the desired speed. The power level is always set based on what is needed to achieve the correct results.

By using P-I-D controller, we can make the steady state error zero with integral control. We can also obtain fast response time by changing the P-I-D parameters. P-I-D is also very feasible when it is compared with other controllers.

In our project, first of all we have obtained the P-I-D parameters for our system. Then we have constituted our own P-I-D algorithm with coding. The P-I-D algorithm and the whole code segments can be seen in Appendix.

3.3 The Block Diagram of the DC Motor Speed Control Loop:

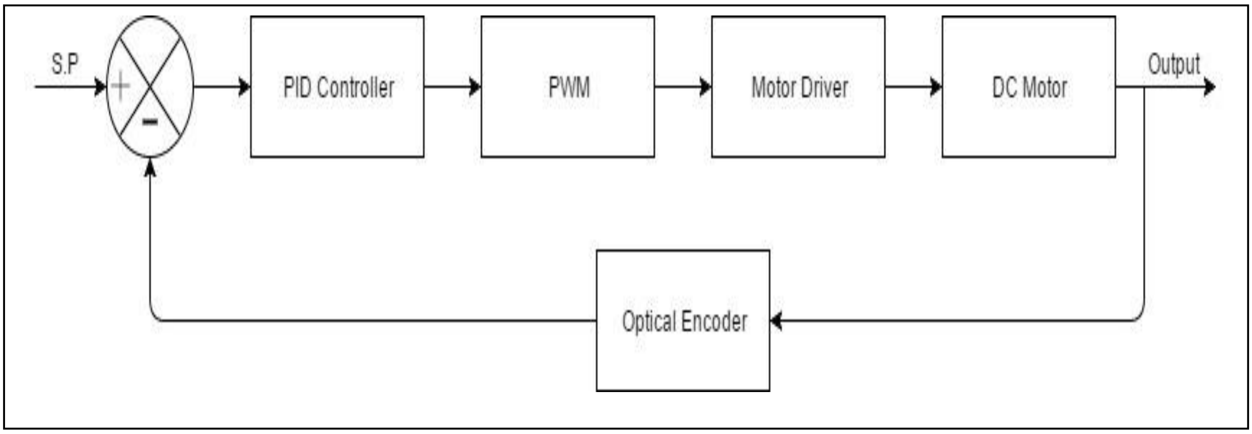


Fig.9. Block diagram of closed loop PID control

As it is seen from the block diagram of the DC motor control loop, the speed sensor (encoder) measure the speed of the DC motor. The output of the PID controller gives the duty cycle of the square wave generator. Data acquisition cards can be used as square wave generators. The output of the square wave generator is motor driver. We have used L298 as motor driver which can supply current up to 2A to the DC motor.

3.4 Feedback Element:

The feedback element used is Double Speed Measuring Module with Photoelectric Encoders

Model: HC-020K.

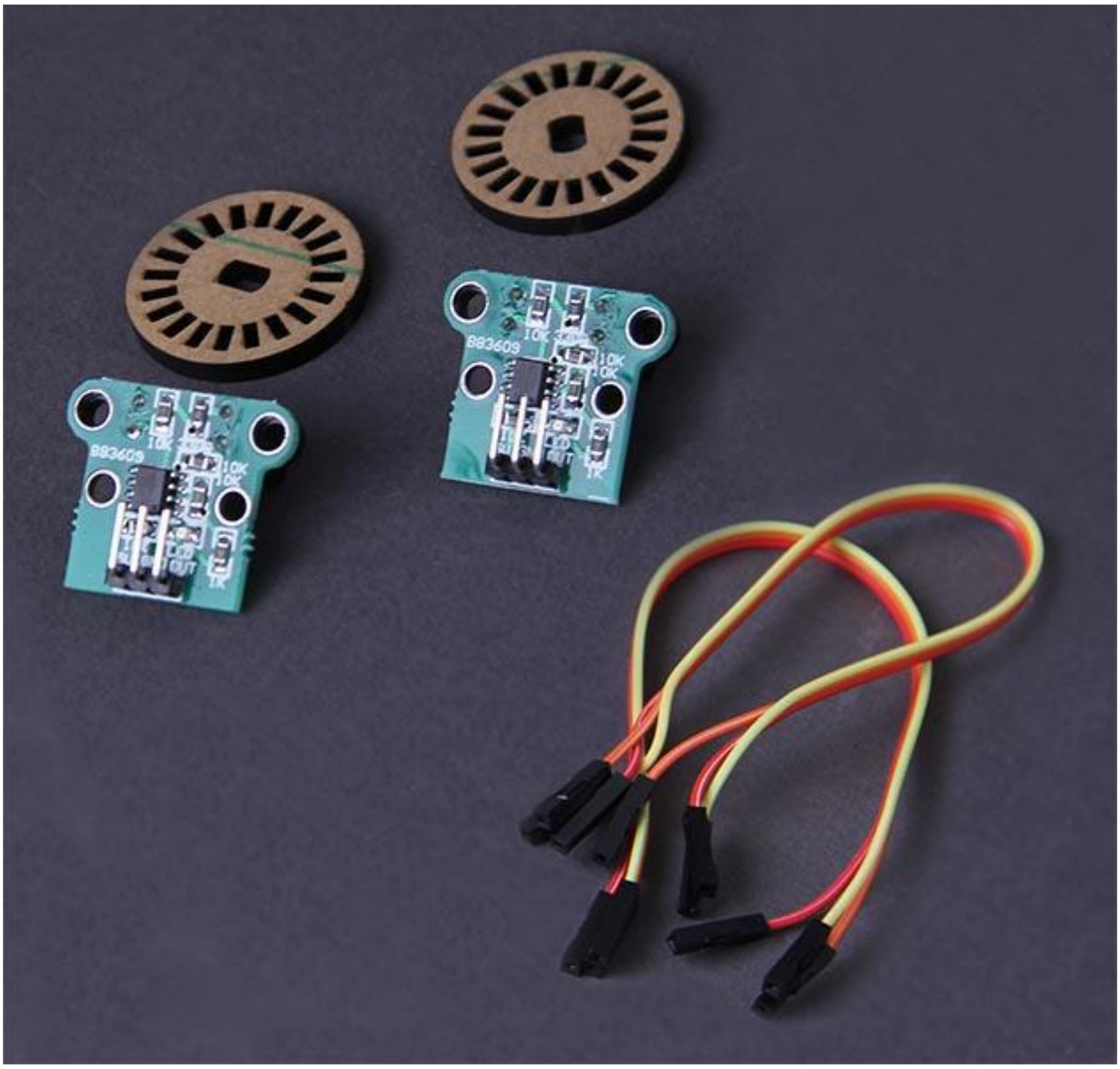


Fig.10. HC-020K optical encoder Module

3.4.1 Features:

HC-020K speed measuring sensor is a wide voltage, high resolution, short response time, and the switch output speed measurement module. It can test motor's rotational speed with black encoder (measured the inner diameter of D type encoder that provided is 4mm, can be used for motor shart w/ 4mm diameter, which is TT motor we matched, yellow shell and white axis).

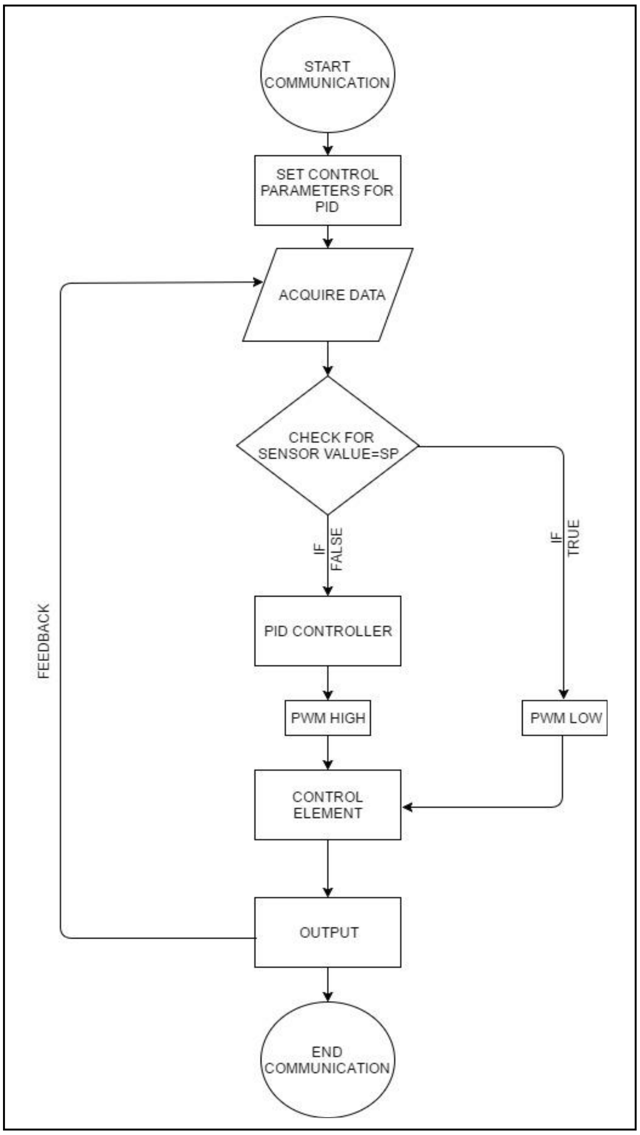
3.4.2 Specifications:

- Module Working Voltage: 4.5-5.5V.
- Resolution: 0.01mm.
- Measurement frequency: 100 KHz.
- Encoder resolution: 20 lines.

3.5 System Software in labview:

Analog input data acquisition options include: *immediate single point input and waveform input*. In using the immediate single point input option, data is acquired one point at a time. Software time delay to time the acquisition of the data points, which is typically used with this option, makes this process somewhat slow. *Waveform input* data acquisition is *buffered and hardware timed.* The timing is provided by the hardware clock that is activated to guide the acquired data points quickly and accurately. The acquired data is stored temporarily in the memory buffer until it is retrieved by the data acquiring VI.

Fig.11. Flow chart



3.5.1 Front Panel:

All programs which are written inside the LabVIEW environment are called VIs. Each VI consists of a Front Panel and a Block Diagram. The Front Panel includes various controls and indicators while the Block Diagram contains various functions and other VI's, that are inter-wired among themselves. Shown in Fig is the Front Panel of the DC motor control VI. As shown, the Front Panel includes two Waveform Charts and other objects. The top Waveform Chart displays the error signal (the difference between the set point and the process variable), and the bottom chart displays VCO, the Controller status. Other objects inside the Front Panel includes the recessed box with two digital controls. They are used by the operator to input the Set Point (VSP) value of and the scaling factor (T Calibrate). The last object in the Front Panel is the Run/Stop switch which is used to initiate and terminate the VI execution.

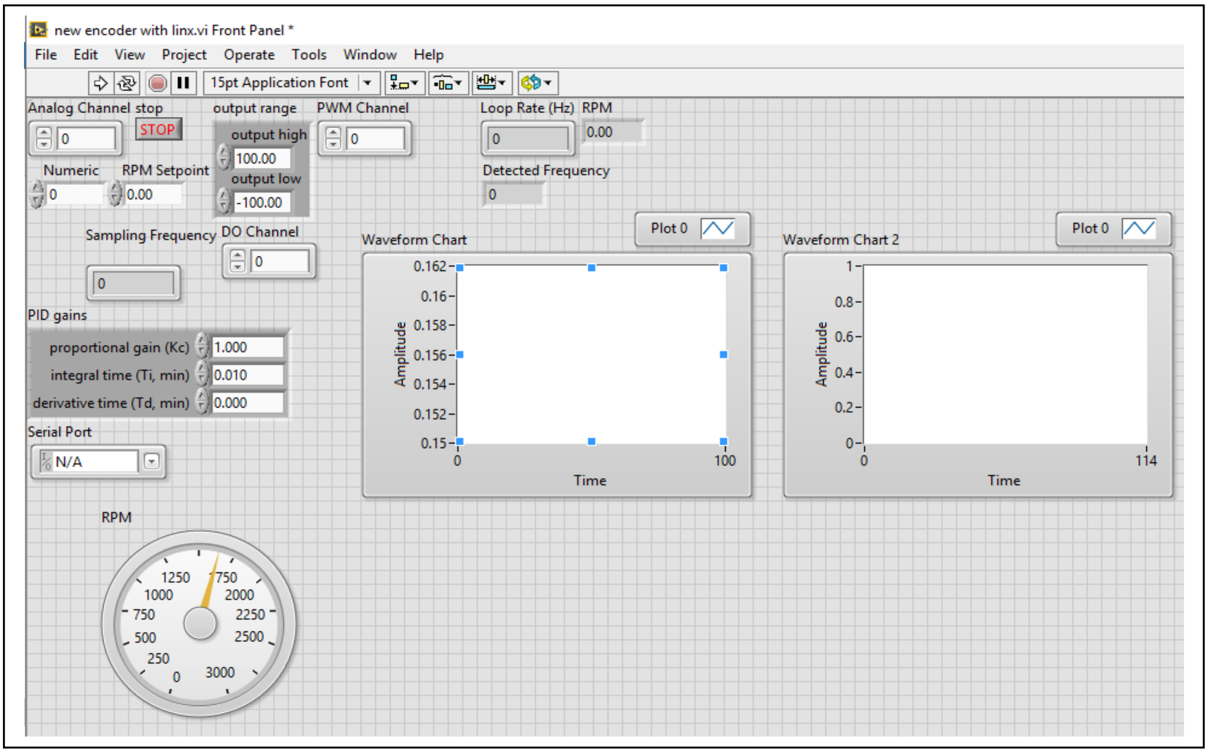


Fig.12. Front panel of LV

3.5.2 Block diagram:

The Block Diagram is the graphical program that shows the data flow of the temperature control operation. Unlike a high level language program, like the C language where instructions are executed in the order that they are written, the execution of a LabVIEW VI depends solely upon the flow of data: a particular object inside the Block Diagram will execute only if data is available or present at all its input terminals. The execution continues at each node that has the data.

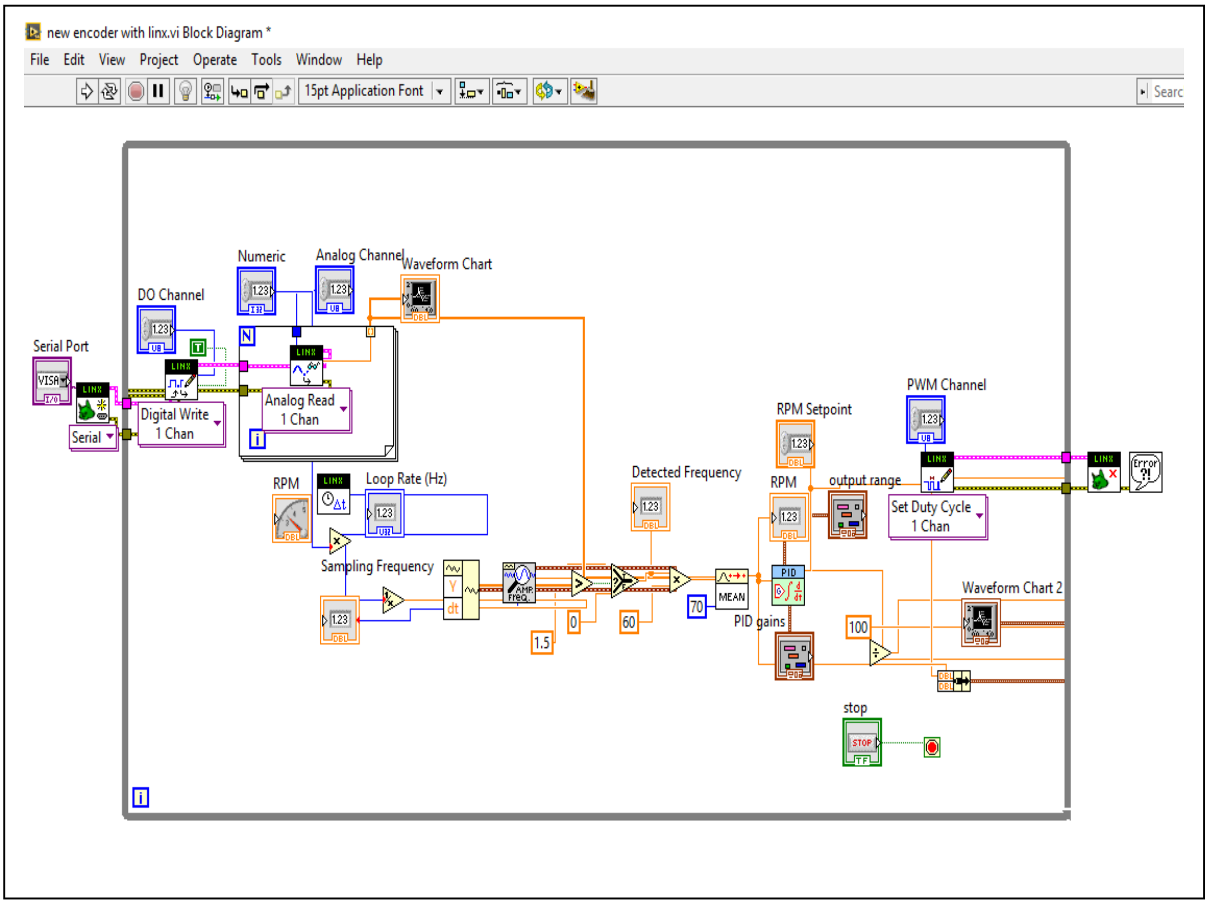


Fig.12.Block diagram in LV

CHAPTER 4

4. CONCLUSION:

In this thesis, dc motor speed control system is designed with different controller by using Circuit Design and Simulation tool in LabVIEW. Different controllers used are on/Off, Proportional (P), Proportional Integral Derivative (PID) to design the controller for speed control of dc motor. Comparison between the performances of different controllers is studied and as a result the response of PID controller is more accurate than other controllers. So, this controller is selected for the speed control of dc motor system. Also all types of controllers are designed in LabVIEW. There may be other software used for designing control system but LabVIEW is the simplest of them all. It is because it uses the drag and drop principle, it doesn't need any code to run the software since it follows graphical coding.

Also the cost of DAQ card is drastically reduced using the AVR microcontroller. The system response using the proposed DAQ card is yet to be studied and compared with the traditional DAQ card.

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