TESTBENCH FRAMEWORK FOR TESTING HARDWARE INTERFACES OF EMBEDDED BOARDS

A Thesis submitted in fulfillment of the requirement for the Award of the Degree of

MASTER OF TECHNOLOGY

In VLSI Design

Submitted By

SHASHI KANT YADAV

601762016

Under Supervision of

Dr. Sujit Kumar Patel

Assistant Professor

ELECTRONICS AND COMMUNICATION ENGINEERING DEPARTMENT

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY (DEEMED TO BE UNIVERSITY), PATIALA, PUNJAB JULY 2019

STRYKER GLOBAL TECHNOLOGY CENTRE

Gurugram, Haryana 122002, India

Date: Jul 10,2019

CERTIFICATE

This is to certify that **Shashi Kant Yadav** (Regn. No. 601762016), a student of M.Tech.(VLSI Design), **Thapar Institute of Engineering and Technology, Patiala** has successfully completed one-year (June 2018 – June 2019) internship program in **Stryker Global Technology Centre, Gurugram**. His title of dissertation is **"Testbench Framework for testing hardware interfaces of Embedded Boards".**

During the period of his internship program and in continuation, he was punctual and hard working. I wish him every success in life.

Pankaj

Mr. Pankaj Joshi

Senior Staff Engineer

Stryker India Pvt. Ltd.

DECLARATION

I, Shashi Kant Yadav hereby declare that the work presented in this thesis "**TESTBENCH FRAMEWORK FOR TESTING HARDWARE INTERFACES OF EMBEDDED BOARDS** " in the fulfillment of the degree of Master of Technology (VLSI DESIGN) submitted at Electronics and Communication Engineering Department, Thapar Institute of Engineering and Technology (Deemed to be University), Patiala has been carried out under the supervision of Dr. Sujit Kumar Patel (Assistant Professor, Electronics and Communication Engineering Department, TIET, Patiala) from August 2018 to July 2019. The matter presented in this is authentic and have not been submitted to any university for the award of any degree.

Date: 02/09/2019

Shashikant

Shashi Kant Yadav

601762016

02/09/2019

Dr. Sujit Kumar Patel

Assistant Professor

Department of Electronics and Communication Engineering

Thapar Institute of Engineering & Technology

(A deemed to be university) Patiala, Punjab

Date: 02/09/2019

ACKNOWLEDGEMENT

I would like to express my gratitude to Dr. Sujit Kumar Patel, Assistant Professor, Electronics & Communication Engineering Department, Thapar Institute of Engineering and Technology, Patiala for his patient guidance and constant support throughout this thesis work. I am thankful for the opportunity to work with him and for his invaluable guidance.

I am also thankful to Dr. Alpana Agarwal, Head of the Department of Electronics & Communication Engineering, TIET, Patiala, for providing this opportunity to me.

I also want to express my gratitude to the lab assistants of VLSI Design Labs – Mr. Manohar and Mr. Ajay for their help in all the possible ways for successful completion of this work. I thank all those who have helped directly or indirectly in this work.

Lastly, I would like to thank my parents, my siblings- Ravi and Jaya. My friends for their constant support and encouragement throughout the making of this report.

Shashi Kant Yadav

M.Tech-VLSI Design

Roll No: 601762016

ABSTRACT

Due to continuous scaling down in the Embedded technology, and hence the boards have become more prone to the hardware working strikes and the sources of hardware working strikes can be many like irregularity in board design, wrongly reading of schematic and wrongly fabrication. The hardware interfaces play a vital role in application/integration of board with other devices. Thus, the hardware testing is a very important procedure after the board get designed. Manually it is very difficult to find the hardware interface health and its working condition whether it is good or bad. Thus, the problem of concern is the reliability of the board affected by the hardware working strikes. So, a Testbench framework has been proposed for testing of different hardware interfaces on any embedded board. Later, in this thesis work application is proposed which inherently testing the Ethernet interface and also logging the data over the Graphical user interface of the Ethernet module designed.

It contains the analysis of Ethernet based speed controller for DC motor using arm cortex processor. The implementation of ARM-oriented controller as a programmable controller to drive is used with the following benefits: The hardware conformation to control data accumulation is decreased as ARM- controller includes 12-bit A/D and PWM generator as an in-built feature. As a result, highly accurate outcomes in terms of calculation are seen alongside the PID control. Controlling program accumulated in 256 KB of flash ROM of microcontroller, or external interfacing memories, as well as DC motor speed exploration specimens, are transferred to a remote computer for storing in the database.

The ability of standard Visual Studios 2010 alongside Origin 6.1 packages is utilized to control, display as well as represent graphically (GUI). The GUI here used is capturing the speed in (rpm) which is being controlled by the third order PID controller. Keil4 IDE using JTAG debugger can debug as well as simulate the embedded C language Program Code analysis.

With the help of developed Testbench framework we can easily test any of the hardware interfaces of any embedded boards which includes Raspberry Pi, Beagle-bone etc.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Embedded systems act an important part of our daily life being used in the form of appliances like cell phones, handheld PDAs (personal digital assistant), cameras etc. The unprecedented growth of embedded systems in our lives have led to increased production of these systems and the competition has forces industries to be cost effective, reliable and with shorter time to market. Industries involved in development of embedded system are aware that high quality and reliability of their product plays important role for their sustenance in market.

These constraints lead to rigorous testing which is expensive and time consuming. On the other hand, time to market has become an important parameter for embedded system market hence an intuitive test method is necessary to automate the testing process without a compromise on quality. Boundary scan testing is widely used in circuit testing of electronic systems. IEEE 1149.11 is widely adopted for in-circuit test to validate placement of components, opens between driver and receiver, short between differential pair and short across capacitor. Tests for path delay faults are also achieved using random access scan. Boundary scan tests are also used in backplane testing for multi-drop test architecture. The above boundary scan test techniques are efficient for PCBA level testing for the quality of assembly line but do not have the functionality test of the system. For testing embedded system, it is necessary to validate not only the hardware quality but also the software quality. Embedded systems must use hardware and software together to meet system functionality. Hence hard- ware software co-validation techniques evolved. Various hardware software co-validation models like Textual Fault Models, Control-Dataflow Fault Models, State Machine Fault Models, Gate-Level Fault Models and Application specific Fault Models. Hardware software co-validation techniques for embedded systems includes simulating or emulating a system requirement with a given test input sequence. Co-validation process has three major steps, test generation, co-simulation, and test response evaluation. The co-validation testing techniques are efficient than the boundary scan test in terms of system functionality test. But co-validation test is majorly based on state machine level and fall short of testing the overall system functionality.

For testing of embedded system, a hardware software interaction-based technique is proposed. This technique focuses on test data selection based on fault injection in hardware and converting it into software fault for selection of test data. A target based, and host-based testing is proposed. It involves inserting application in the device under test and connecting it to host with test scripts to test the services.

Hardware interface is an architecture used to interconnect two devices together. It includes the design of the plug and socket, the type, number and purpose of the wires and the electrical signals that are passed across them.

1.1 EMBEDDED BOARD TEST

Embedded Board Test describes a test method for modern electronics, using the intelligence of built-in circuits. Various technologies are used, having one thing in common: both generation and application of the test scenarios takes place in one system. The test system consists of a unique, modular control hardware and software.

Embedded Board Test allows digital, static test of pins and networks. Functional tests can also be integrated. These include access to I2C and SPI components, measurement and evaluation of analog processor inputs, dynamic memory tests and test of high-speed interfaces (e.g. USB 3.0.)

Typical production faults such as short circuits, missing resistors, non-soldered pins and BGA balls, but also errors in high-speed data transmission are can be found quickly and efficiently. The short execution time and accurate fault diagnosis allow cost-optimized repair.

A total of four combinable technologies form the pillars of the Embedded Board Test.

1.1.1 JTAG based test access (Boundary Scan) -

The standardized method simply addresses complex components such as FPGAs, processors, controllers and CPLDs. Detailed hardware knowledge is not required. JTAG/Boundary Scan - is probably the most ingenious test process.

1.1.2 Boundary Scan

Boundary Scan is an electrical test method, detecting structural errors in circuits. Scan test essentially means “testing at the periphery (boundaries) of a circuit”. To implement this sort of testing, GOEPEL ELECTRONIC has developed the principle of interaction of various hardware components which includes -

i. controller,
ii. input/output(I/O) Module,
iii. Tap Transceiver and
iv. unit under test (UUT).

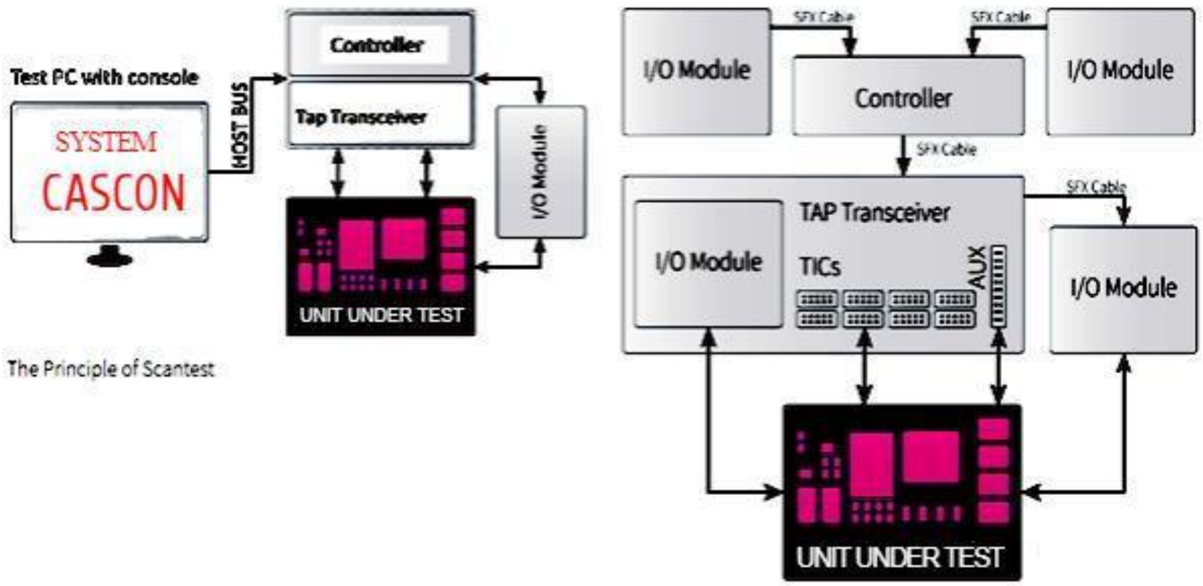

Figure 1.1 System CASCON

1.1.3 FPGA Based Test

This method integrates the FPGA logic into the test. Even complex test applications are easy and efficient to solve with Chip-VORX. Access to internal Gigabit links and other functionalities (frequency measurement, flash access, RAM tests) is possible via universal FPGA models (no separate adaption necessary).

1.1.4 Chip-VORX

Chip-VORX is an IP-based technology for implementation, access and control of Chip embedded Instruments via IEEE Std. 1149.x/JTAG. It also supports FPGA embedded instruments in the form of soft-cores. The Chip-VORX library currently contains more than 300 different test and measurement instruments for all leading FPGA platforms. The usage of Chip-VORX requires neither expert background knowledge nor specific FPGA tools or continuous IP adjustments.

The FPGA-integrated Chip-VORX models are functional software IPs. This allows you to configure FPGAs individually to use them for functional testing. The capabilities already provided by FPGAs or CPLDs are used to increase test coverage and speed.

Which applications can Chip-VORX perform?

i. high-speed in-system flash programming
ii. High-speed access test of DDR-SDRAM (at-speed access)
iii. universal frequency and clock measurements
iv. Bit Error Rate Test (BERT)
v. Control of IEEE-1687 instruments (IJTAG) as well as pure IEEE-1149.1 instruments
vi. interactive tests with boundary-scan operations

1.1.5 Processor based test (VarioTAP)

A processor-specific model allows the processor to enter the debug mode. With VarioTAP individual functions (analog registers, flash access, real-time RAM tests) are addressed. Both the JTAG port and other debug interfaces are supported.

VarioTAP Test & Programming of processors / Processor emulation- The VarioTAP IP technology is used to control a processor using the debug port. You use VarioTAP to access the register level of a microcontroller and use its integrated structures. You can access it via the JTAG interface or other debug interfaces (e.g. SWD or DAP). If you are using a controller that does not support Boundary Scan, VarioTAP is a very good alternative.

The functional structure has multiple stages:

i. flash programming both on-chip and external (e.g. eMMC, NAND, SPI Flashes)
ii. functional tests (e.g. Read ADC, DDR Ram Test)
iii. own tests via open interfaces

In principle, all modern processors and microcontrollers are supported. Everything works in combination with the SCANFLEX hardware, which can be dynamically adjusted to the respective debug interface (JTAG, BDM, SBW, SWD, COP, etc.).

1.1.6 Processor based test with a universal (JEDOS)

Using JEDOS (optimized for test and programming applications), complex function tests with a graphical user interface are realized. These are complete memory tests, efficient flash access or interfaces tests (Ethernet, USB, etc.). The tests can be created in the shortest possible time without special hardware knowledge. JTAG Embedded Diagnostics Operating System (JEDOS) can perform functional tests in real time using the native processor. It provides maximum fault coverage and comprehensive diagnoses for digital, analog and mixed-signal components. The fully functional operating system is loaded via JTAG. Neither flash firmware nor special test software is required.

1.1.7 Hardware Testing

Hardware testing is to check/ensure the functionality, stability of hardware component and ensure that it should not have process fault. It also includes the heavy workload task for memory and CPU to check the performance and durability. Nowadays hardware design become much complex which demands the methods for testing to adhere and adapt to the challenges that arise, hence test development with new standards for hardware become advance. There are many components involve in hardware testing like BIOS, CPU/Processor. Test the hardware to ensure its logical correctness and to ensure that follow appropriate standards. Using functional tests to determine whether met the test criteria, there are the few techniques commonly used for hardware testing.

i. The Software-Based Self-Testing: These days microprocessors impose significant challenges to the testing hardware, because of their high complexity and heterogeneity. The software-based self-testing alternate way to hardware testing. The benefit of software-based self-test is that it can be applied in the normal operation mode of the microprocessor, thus applying the required tests at-speed.

ii. The ATPG (Automatic test pattern generation): Starting with a chip netlist, inserting scan-chains which is a technique used in design for testing, and generating vectors is the most direct and effortless approach and doesn’t require complete knowledge of the DUT

(Device under test). The recent EDA (Electronic Design Automation) tools can deduce how to partition a design into blocks, and to isolate them by scan-chains.

iii. Built In Self-Test (BIST): BIST is best for testing complex system, due to less accessibility to internal nets as design complexity increased, has spawned various design techniques that increases testability. BIST implementations are based on full scan architecture. This means that all the storage elements in the DUT concatenated to form several scan chains. These way test patterns can be serially shifted in and out of the storage elements. BIST requires no interaction with a large, expensive external test system. The testing is all built-in and only tester is needed to start the test.

There are many tools available for hardware test and hardware diagnose like -

iv. Automatic Test Equipment (ATE)

v. Sandra Lite – Si Software

To execute load tests, simulate and observe variety of conditions and using or exceeding the amounts of data that could be expected in an actual situation. Following tools allows to measure different aspects of a system.

vi. Bonnie++

vii. IO Zone

viii. Net pipe

ix. Lin pack

x. NFS Connection package

1.2 TEST BENCH FRAMEWORK

It is the framework designed for testing hardware interfaces on Embedded Board. The Hardware interfaces consist of UART (Universal Asynchronous Receiver/Transmitter), Wi-Fi, Ethernet, CAN (Controlled Area Network), eMMC (embedded Multi-Media Controller), USB. There is a continuous scaling down in the embedded technology, and hence the boards have become more prone to the hardware working strikes. The sources of hardware working strikes can be many like irregularity in board design, wrongly reading of schematic and wrongly fabrication. The hardware interfaces play a vital role in application/integration of board with other devices. Thus, the hardware testing is a very important procedure after the board gets designed. Manually it is very difficult to find the hardware interface health and its working condition whether it is right or bad. Thus, the problem of concern is that the reliability of the board is affected by the hardware working strikes.

1.3 PROJECT OBJECTIVES

Testing of hardware interfaces using application design in C language is the area of focus. Reducing manual testing is the area of concern. Making the deployment of the board efficient and fast is the area of concern. Health monitoring of the hardware interfaces is the area of concern. Integration of Board with other devices with all hardware interfaces in working state is the major area of concern.

1.4 METHODOLOGY

The Testing Frame Work is designed with the help of two programming languages one for GUI (Graphic User Interface) i.e. C# and one for application i.e. C programming. The Test Frame Work GUI consists of different Tabs that include different hardware interfaces which get communicated with the embedded board with C application running in background. The default communication is serial via USB to RS-232(UART) and Molex cable that directly inserted into the board. The board is connected to Linux Ubuntu machine (14.04) via type b and type a USB. The data send from the GUI and received at the Ubuntu machine and again revert to the GUI thus making a complete communication path.

1.5 TASKS

Study of single event mechanisms, soft errors occurring in the Hardware design is the area of concern. Analysis of schematic and fabrication. Detailed analysis of conventional hardware interfaces. Proposed hardware/software testing techniques. Writing C application which is running on Board. Result and conclusion.

1.6 OUTLINE

Chapter 1 gives the introduction to Embedded systems and its testing methods which includes Boundary Scan, FPGA Based Test, Chip-VORX Testing and Programming, JEDOS for complete memory test, Hardware Testing which is the most important testing that ensure the functionality, stability of hardware component by checking the process fault. It also explains the testbench framework for testing of different hardware interfaces on Embedded Board.

Chapter 2 includes detailed literature survey which contains research work done till now associated with implementing proportional-integral-derivative (PID) theory or logic controller to proceed the controlling of speed and direction of DC motor. The implementation is done with the help of feedback method, hybridized PID controller with the help of fuzzy gain scheduling and tuning of the controller, analyzed and designed PID controller network to fetch steady state feedbacks. It contains design approaches of PID controller for DC motor using arm cortex processor.

Chapter 3 includes the overview of Embedded System which explains about Arm Processor Technology which we are using in development of Ethernet based DC motor speed control.

Chapter 4 gives the implementations of the basic DC motor structure. The current investigation regarding designing as well as progress of PID logic controllers for DC motor speed function. As the DC motors are utilized particularly in maintenance of speeding functions, the speed is among the significant procedure factor which is to be observed and regulated within commerce. The principle and block illustration of the DC motor speed control system based on ARM processor is exemplified. The block diagram comprises an LM3S9B96 controller based on ARM processor, DC motor having optical sensing component, frequency to voltage (F/V) converter along with a personal computer. The optical encoder recognizes the motor's speed thereby converting it to a sequence of TTL attuned beats. Frequency is produced in proportion with the motor's speed. This frequency is transformed into proportionate voltage through frequency to voltage (F/V) converter. Microcontroller obtains the voltage via inbuilt 12-bit A/D converter. This empirical work uses the output of the PWM signal to be associated to the DC motor by means of the L239D driver circuit for controlling the motor, the Pulse-width modulation signal is sent through driver circuit for securing the controller board from the back EMF resulted by the DC motor in the duration of forward as well as reverse directions. The controller signal will be increased by the driver circuit and this signal is not able to drive the motor, therefore the motor will be energized.

Chapter 5 gives the conclusion and future scope of the research which shows the design of the control system performance with respect to the above-mentioned procedure control application. ARM processor is the most useful one as it has real time clock (RTC) as well as PWM as built-in characters. DC motor speed control system gives in that the PID logic controller showed the most optimal execution when all these mentioned experimental conditions are preserved. The PID generated ± 0.28 RPM control with respect to a step size of 3000 RPM. So, PID is the most useful option for DC motor speed control implementation. The ARM-oriented D.C motor speed control with the help of PID logic shown here generates a better performance in a dynamical way in comparison to another present microcontroller dependent DC motor speed control. The simplistic design with flexible aspects of the PID controller is the major plus point.

The information generated from the microcontroller design as well as study of PID logic controller with respect to DC motor speed controller systems, the recommended empirical evidence is described in the following for futuristic studies

Work of suggested controllers is researched to study the set point differences, load variations, influences in terms of random noise.

Development of a self-learning (auto-tuned) fuzzy control algorithm for using in the computer as well as a microcontroller with respect to process control terms

Designing and studying the implementation of the above controllers to other procedure control system like DC motor positional aspect as well as AC motor and Servo motor speed control and so on.

CHAPTER 2

LITERATURE REVIEW

As far as a detailed literature review is concerned about the development of speed controller, this study is aimed at implementing proportional-integral-derivative (PID) theory or logic controller to proceed the controlling in the following manner.

Seugwan et al (2015) postulated the proportional-integral (PI) proportional-derivative (PD) controller with the help of PID feedback method for overcoming the issue of reactive control behavior that comes with active queue management (AQM) suggestions. A detailed comparative analytical research was done by considering different types of network atmospheres as well as PI-PD controller execution, faster and arbitrary identification, PI controller with respect to queue length dynamic, the proportion of packet loss, along with the ink usage. Nearly a century age, the work done regarding speed control was done by Harry Ward Leonard and his research work “Volts versus ohms – speed regulation of electric motors”, was presented at an American Electrical Engineers conference [11,32]. There was a rotating rectifier with a grid-supplied induction machine to rotate a DC generator. Through modulating the magnetization of the DC generator, it was doable to control for DC motor speed control by means of controlling DC voltage. However, three machines were needed, and at that point, the speed regulated drive was vital. After introducing the transistors and first micro-processors were, chopper methods like the pulse width modulated (PWM), made it possible for speed control of DC tools accurately.

During the first half of the 1960s, brushless DC motors along with magnets that were permanently attached to the rotor came into being. Although those were not much strong, the power spectrum wasn’t unlimited as well. But the permanent magnet synchronous motor (PMSM) motors enabled the benefits of applying field-oriented control, PMSM motors to dominate the motion regulation. In present days, the fundamental advantage makes the use of brushless AC tools alongside sinusoidal excitation a preferred choice. Practically it means to work like a permanent magnet synchronous motor. As per the report by Zhuo Ruan et al (2011), the dual-mode PID control micro network is practical and is set based on CPLD as well as reconfigurable FPGA. Configuration of speed with the dual mode controlling mechanism, and a comparative aspect with micro-controller unit (MCU) and FPGA based on actual time logic were key points. For converting every controlling data into weight as well as threshold marks, the dual-mode PID controlling mechanism is used on back proportional neural networks. Besides, it is also stored in back propagation algorithm (BP) neural network with respect to the real time. The researchers have said that the regulated network or purpose are adjustable in automated way to minimize the work pressure. After amplifying the external disturbing factor, for adjusting the control accuracy, the neural-network lesson can be resumed.

Jen-Yang Chen et al (2009) proposed a hybridized PID controller with the help of fuzzy gain scheduling, rather than polishing and improving the factors of microcontroller utilized by traditional methods. They stated that factors or parameters of actual Ziegler Nicholas PID are not changed by system function and that is a plus point of this method. Ultimately, the method gives a better and useful oath for constructing the PID regulator. The scholars analyzed the simulations of hybridized PID controller as well as the Ziegler Nicholas PID controller.

According to the presentation by Jain Tang (2011) real time DC motor controlling was presented with the help of TMS320C31 DSP system. MATLAB operational basis of a PID controller for generating a coefficient-series in association with a desirable set of features of controllers. These controller coefficients fall under an assembly language program that uses the PID controller. With the help of 31 digital signal processing starter kit (DSK), the digital PID controller was successful as it was used to test a DC motor speed as well as the positioning control aspect in terms of real-time speed control. As per the outcomes, the PID controller made it beneficial by eliminating the steady error to fetch the desirable output speed.

Moradi et al (2013) stated that the optimized signal from PID control is almost the same as that of the model-based predictive controller (MPC). The controller is decreased to the similar structure of traditional PI as well as PID controller with respect to first order and second order systems. Both PID and MPC optimal marks are alike and the scholars stated that it is usable for any system order which is a benefit. The PID modification is utilizable for adjusting the execution of the controller as well.

Yun Li et al (2016) analyzed and designed PID controller network to fetch steady state feedbacks. Even they mentioned about the issues with the integral and derivative terms, as well as PID design tools and forthcoming directions. PID implementation was elaborated in association with the sustained study and growth for harboring the best from PID. The study is aimed at searching the futuristic method or technology to tune PID.

Basilio et al (2008) stated the benchmark composition by applying to PID controller designing as well as application. A real system is the precursor of a benchmark where a first order system in association with time delays. In this system, the time delay as well as the time constant differs.

With respect to benchmark designing plant, the PI-PD controllers are made. PID operation is used to implement the benchmark plant. This value-processing is programmed by logic regulator/controller, releasing an ‘on or off’ category of signal to drive the regulator circuit of a solid-state relaying part. It results in the system by means of sinusoidal voltage source of 220V. Ultimately, the presentation of the real network simulation outcomes is done.

Munro et al (2012) postulated a modification tool of PID controlling alongside its merits as well as demerits. As per their conclusion, PID controlling has been a beneficial plan that needs further study as well as exploration. Current study of the PID controller design results in novel paths to determine the marks of the proportional Kp, integral Ki, as well as derivative Kd functional tools with respect to a provided linear system-structure.

Yusof et al (2014) postulated the implementation of self-modification PI controller to a water bath temperature regulation system. The entire system structure was interfaced to the computational and controlling algorithms with the help of ‘C’ language. The outcomes presented that the self-tune of PI worked more effectively as compared to the PI controller.

Reddy et al (2011) presented the application of proportional, integral as well as derivative controller (PIDC) in the MATLAB environment with respect to real-time DC motor speed control. As per the outcomes seen, a more effective control function in terms of increased time and steady feedback was observed.

Liu et al (2013) represented a havoc tracking controller system planning by using one short stroke permanent magnet motor in the linear drive. PI as well as PID controller designs were made by them. With the help of real actuator data, the simulation outcomes of the PI, PID controllers were created. Apart from that, when high value exponential disturbance force was present, track down of smooth trajectories were performed and the error values were not beyond ±60 microns.

Leehter Yao et al (2015) suggested fuzzy PID controller. This apart from being used as an adaptive fuzzy PID controller that adapts to different system dynamics is good for considering as a normal fuzzy PID controller flexibly. The suggested result set fuzzy PID controller works well while regulating the system exempting different dynamics.

A.Visioli et al (2009) gave fuzzy logic, with respect to the tuning of PID controllers. When it comes to determining the value of the weight, multiplying the set benchmarks with respect to the proportional function, a fuzzy inference strategy is used on the basis of current output error as well as its time derivative. Thus, the rise time within the set point might be decreased apart from overshooting both terms. The values of the proportional result as well as the integral and derivative time constant are obtained as per the famous Ziegler-Nichols law/equation to fine load disturbance attenuation can be achieved.

Chandrasekhar et al (2010) gave design of embedded dependent DC motor speed controlling system. With the help of microcontroller, a successful implementation of PID controller was done. It was tested on a DC motor speed controlling system. To regulate speed, the analytical outcomes presented that when the PID controller was used it was possible to obtain the wanted result. Ibrahim Kaya et al (2013) postulated PID controllers for using in industries and these are still in use. A good closed loop work has been offered by the PI-PD controller to control procedures with resonances, integrators as well as unstable transfer operations. The researchers gave an easy tool for getting the optimal parameters for a PI-PD controller out of those from the PID controller to get a better closed loop system operation. Extensive simulation instances are shown for illustrating the value of the recommended method. Jose L. Tong and James (2012) represented a digital PID that sets a proximal association between the analog as well as the digital PID. An experiment or test is done with the works or functions of designed/simulated digital PID controllers alongside the analog PID with respect to the time and frequency domain. Lastly, the researchers stated that the digital PID is more effective presenter than the analog PID controller.

Tan et al (2013) postulated an easy tool to calculate the stabilizing PI controllers. In this proposal, stability boundary locus (kp, ki) plane is the way to plot; afterwards, computing the stabilizing markers of the factors of a PI controller is done. The (kp, kd) plane and (ki, kd) plane are used to obtain the limiting values of the PID controller that makes a system stable. Jianxin Tang (2017) suggested a real-time DC motor speed as well as position controlling with the help of TMS320C31 digital signal procedure starter kit. A PID controller is made with the help of MATLAB operations for getting a coefficient-series in association with a few desirable features of controller. As per the outcomes, improved system results from a PID controller, matches that of the real system outputs as per the hypothetical values.

Mohamed et al (2018) submitted the use of a novel PID controller having a PM motorized drive system. The suggested algorithm of controller has been inferred as being appropriate for applied to every procedure irrespective of the method prototype or strictures. The model of drive system has been created along with a replication being performed for an operation forecast within dissimilar loading circumstances with dissimilar command indications. The outcomes of the mockup specify that the PID controller is operative and strong for systems of PM drive.

A. Rubaai et al (2008) demonstrated a combined setting for the fast modelling of a strong fuzzy-PID controller which permits quick understanding of new plans. The design of the fuzzy PID controller as well as its incorporation with the standard PID in a universal controlling system is established. Tentative outcomes present that the projected crossbreed fuzzy PID controller generates greater control operation compared to the usual PID controllers, especially in supervision of nonlinearities and peripheral turbulences.

Dan Sun Jung Meng et al (2006) demonstrated an adapting sole neuron based PID rapidity regulator for substituting the conventional PID controller typically utilized in the error accepting 4-switch 3-phase (4S3Ph) inverter fed PMSM (permanent magnet synchronous motor) DTC (direct torque control) drive structure for improving the operation of the system. Dong Hwa Kim et al (2014) demonstrated designing method of PID controller with rebuff task against peripheral disorder in motor regulator system with the use of secure algorithm. Until the currently, PID Controller were utilized for operating AC motor driver due to its application recompenses under operation and typical arrangement. The structures of PID controller are chosen through protected algorithm for obtaining the needed reaction.

Saeed Tavakoli et al (2013) demonstrated tuning PID controllers because of prime ordering along with time delaying systems using examination of dimensions and mathematical adjustment methods as an optimum technique, thereby reporting that the suggested technique has a significant advantage over standard methods. Additionally, the closed loop structure demonstrates a sturdy operation faced by uncertainty of prototype structures. Astrom et al (2008) exhibited a novel designing technique for PID controllers, according to adjustment of rebuff of loading disruption having restraints over sturdiness to prototype ambiguities. The project distributes structures for dealing with dimension noise as well as set-point reaction as well. Hence, the preparation of the designing difficulty catches 4 vital facets of manufacturing controlling difficulties, resulting in a restrained adjustment difficulty that may be resolved with iteration. Bao-Gang Hu (2011) showed an evaluative method on functionality for a methodical research of fuzzy PID (proportional-integral-derivative) like controllers. This method is employed to derive procedure-independent designing strategies from making note of 2 matters: simplicity and nonlinearity. They testified the plainness of fuzzy PID controllers thereby concluding that direct-action controllers display plainer designing features than gain-planning controllers.

Manoj et al (2007) exhibited a pictorial designing technique to obtain the whole array of PID controller gains which strongly steady a system while delays in time occur as well as ambiguity of additive occurs. This designing technique chiefly relies over the system's frequency response that may aid in reducing the difficulties that are part of plant forming. The fact that parametric uncertainties and time-delays are nearly extant all the time in live developments making their controller designing technique quite important to control processes. They have employed the designing method to a model of DC motor having an interaction interval and a sole area non-reheat steam production element. The outcomes were agreeable and strong steadiness was attained for these disconcerted plants. Datta (2013) exhibited a range of PID controllers steadying an initial-order plant having time-delay, thereby resulting to the event of a random order plant having time-delay.

Sujoldzic et al (2013) demonstrated a process to stabilize a direct time-invariant plant of every sequence having time delay using PI (proportional-integral) and PD (proportional-derivative) controllers. The technique established through this is founded on calculating the constancy edge with regards to the comparative and essential expansion for the case of PI, and likewise, comparative and imitative increase in case of the PD.

Emami et al (2018) demonstrated a pictorial method to find every PID controllers which steady a specified SISO (single input-single-output) LTI (linear time-invariant) system of every sequence having time delay. They presented a technique which finds every PID controllers which fulfill an $H[\infty]$ weighted sensitivity restraint as well. This difficulty may be resolved through locating all PID controllers which concurrently even out the closed-loop features polynomial thereby satisfying restraints demarcated with a range of linked complicated polynomials. A chief benefit of this process is the matter that has no need for the process of plant transfer, just its response of frequency. Mokrani et al (2013) demonstrated a new strategy of a FSTPIC (fuzzy-based self-tuning TI controller) for speed parameter of a secondary field-oriented IM (induction motor). Under this novel method, the fuzzy regulation of standard PI controller additions is attained via fuzzy rubrics inferred through several strength replication trials employed to numerous induction motors. Such methods were employed due to arrange of functioning circumstances like reaction to stepping rapidity order from halt, application of step load torque and relapse of speed, with trifling limits and an augmented and/or reduced rotor resisting, self-inductance as well as inactivity. Replication outcomes revealed that the suggested fuzzy self-tuning PI controller is improved compared to the static gains one with regard to strength and rapidity increase time, even in case of huge discrepancies of functioning circumstances and disturbance of load.

Junji Yoshitsugu et al (2010) demonstrated a progressive technique for improving the haste reaction physiognomies of an AC servomotor drive system with automatically resonant loads. Motorized resonance as well as anti-resonance is each efficiently repressed according to a loading pace response method for the system of AC servo motion. Patricia Melin (2011) demonstrated stepping motors control processes.

Nevertheless, the disparities of the drive's motorized arrangement, that are mutual among such 2 uses, may cause losses in synchronicity for elevated stepping rates. Furthermore, the standard open-loop rapidity control is fragile, and a closed-loop control ends up being essential. And, fuzzy logic is used for controlling the pace of a stepping motor drive having response. A neuro-fuzzy hybrid method is employed for designing this fuzzy method basis of the smart system to regulate. Vijayakarthick et al (2017) demonstrated MRCS (modified repetitive control strategy) thereby implementing it within a DC motor. The MRCS integrates the notion of RCS (repetitive control strategy) that achieves precise asymptotic setting point tracing under this procedure, only if the phase extent utilized for the controlling preparation matching the real phase of the reference/disturbance indication precisely. The system of DC motor is estimated within a FOPTD (first order plus time delay) model through method of stepping test. RCS is combined within the DC motor control loop of proportional (P) style. The comparative controller stricture is acquired with the use of ZNTR (Ziegler-Nichols tuning rule). The suggested MRCS is combined to the system of DC motor as well. An episodic feedback sign of sine wave is produced and live running of the system of DC motor are performed due to the episodic orientation tracing with MRCS founded P mode controlling loop. A comparable function is conducted as well using RCS based P mode as well as conventional P-mode controlling structure in the loop.

Yasunobu (2017) stated a hands-on designing technique of fuzzy PID controlling system. As it was simplistic structure, the study regarding the manner of choosing the kind of standard PID controllers in case of dissimilar controlled plants is effective. According to the scrutiny of association among fuzzy PID controller and standard PID controller, they suggested a technique regarding the manner of choosing the kind of fuzzy PID controller appropriate in case of the controlled plant. Yamada et al (2010) suggested a designing technique in case of altered PID controllers in a way that the altered PID controller causes the controlling system for keeping unsteady plants steady along with the permissible sequences of P-parameter, I-parameter and D-parameter are autonomous from one another. Once altered systems of PID control are employed over actual plants, the impact of disorder within the plant is deliberated. Within this research, they suggested a designing technique for altered systems of PID control for manifold-input/multiple-output plants for attenuating unidentified conflicts.

El-Gammal et al (2009) confirmed the employing of a novel unit swarm optimization method to adjust the gaining by a PID speed controller confirmatively for giving the least central total error among the speed requirement along with the productivity reaction, least relaxing period, and least overreach for a distinctly stimulated DC drive. The novel method transforms every impartial occupation to a solitary impartial task through stemming a sole total impartial function with the use of quantified or chosen weighing features. As the ideal PID controller limits rely on the chosen evaluating features, the weighing features were handled as active enhancing strictures as well inside the particle swarm adjustment as a double adjustment and universal assortment of PID controller ideal strictures along with finest range of weighing features.

Zheng Jian-ming et al (2011) demonstrated an algorithm of fuzzy PID control through drawing in fuzzy controlling model, that recognizes self-tuning PID strictures and efficiently deteriorate the system capacity, dead zone, the delay in time along with additional drawbacks, the accurateness and constancy of hydraulic location servo system are enhanced. The element stage, square wave as well as cosine input signals are mimicked with PID control and fuzzy PID control.

Anandhi et al (2010) demonstrated a fuzzy logic controller and standard PI controller over an FPGA with use of VHDL for DC motorized speed control. The suggested system is for improving tracing operation of DC motor in comparison with the conventional (PI) control stratagem. They defined the hardware application of 2 inputs (error and alteration in error), single output fuzzy logic controller founded on PI controller along with standard PI controller with the use of VHDL. Live application of Fuzzy Logic Control System (FLC) and standard PI controller is created over Spartan-3A DSP FPGA to control the speed of DC motor. It is detected that controllers based on fuzzy logic offer improved reactions compared to the standard PI controller to regulate DC motor's speed.

Giri Rajkumar et al (2010) demonstrated PID controller that has turned out to be certain in the industries of procedure control because of its effortlessness and efficiency, yet the actual difficulty comes from tweaking this fore fulfilling the prospects. Even though a swarm of approaches previously existing yet a requirement is still there for an innovative system to tune such controllers. CI (computational intelligence) has grabbed the attention of the scientists because of its easiness, reduced computing charge and decent operation, causing it a to be likely selection to tune of controllers of PID, for increasing their operation. This research defines exhaustively regarding GA (genetic algorithm), a CI method, along with its application in PID modification for a live manufacturing procedure that is closed loop naturally. In comparison with different standard PID alteration techniques, the outcomes demonstrate that improved performance may be acquired with the projected technique.

Gopalakrishna et al (2009) suggested the heat regulation of dual pipe system of heat exchanging thereby demonstrating an ant colony algorithm to optimize PID strictures according to standard PID controller. The closed loop element step reaction acquired using the suggested PID likens positively with the one attained with the use of a standard PID controller having active closed-loop model. Further importantly, the suggested method utilizes a portion of time spent through the typical method, devoid of the requirement of upsetting the closed-loop method. Silva et al (2012) suggested the issue of steadying a prime-order plant having dead-phase with the use of a PID (proportional-integral-derivative) controller. With the use of a form of the Hermite-Biehler theorem which applies to quasi-polynomials, the full range of steadying PID strictures is decided for each of the open-loop steady and unsteady plants. The variety of permissible proportionate gains is primarily decided through closed form. In case each proportionate gain within this variety, the steadying put in the place of the essential and derived gains is revealed as being a quadrilateral, a trapezoid or a triangle. In an open-loop unsteady plant, an essential and adequate circumstance over the delay in time is chosen for the presence of steadying PID controllers. Astrom et al (2011) revealed the correctness of the Ziegler-Nichols alteration formulation and revised contextual to PID auto-tuning. In case of PID auto-alteration, it is demonstrated that, for extreme overrun in the set-point reaction, set-point evaluating may decrease the overshoot up to stated values; along with the original Ziegler-Nichols alteration formulation may be reserved. It is presented as well that weighing of set point is greater compared to the standard resolution to reduce huge overshoot through detuning of gaining or sifting of set-point. Nevertheless, in case of extreme set-point undershoots, the alteration formulation will have need modification. In case of PI auto tuning, it is revealed that the tuning formula of Ziegler-Nichols is insufficient and needs to be wholly reviewed.

Gawthrop et al (2010) suggested the incessant-time self-tuning algorithms and demonstrated as having the capability of producing alteration strictures for industrial PID (proportional-integral-derivative) controllers. These are demonstrated as well of having the capability of producing a feed forward signal which decouples the disruption from the interface from neighboring coils in a multifarious state. M.B.B. Sharifian et al (2009) demonstrated primarily a PID compensator that attuned through algorithm of genetics then one more compensator is created through uniting 2 approaches, Basic controller and ideal state response controller. For the secondary compensator, designing stipulations rely over selecting weighing mediums with the use of the GA for finding the correct assessing matrices.

Thus, the operation of the controlling methods is related with regards to rising period, relaxing time, tracing inaccuracy, and sturdiness regarding demonstrating faults and turbulences. The controller designing course and application necessities are deliberated as well. Thus, the contrast among the control of PID and the ideal controlling displays that the ideal controller suggestively decreased the overshoot, settling phase along with having has the finest operations experiencing with system ambiguities.

Asim et al (2016) demonstrated a fuzzy PID controller that may be altered through bearing the alteration rules through PID domain towards fuzzy area. In form of a controller that is nonlinear, regulating a nonlinear procedure extra efficient, fuzzy controller can offer improved operation with regards to rising time along with lesser overshoot. The suggested controller is assessed with the use of few replications. Mehdi Nasri et al (2007) showed a PSO (particle swarm optimization) technique to determine the optimal PID (proportional-integral derivative) controller strictures, for controlling the speed of a linear brushless DC motor. The suggested method has greater facets, counting simple application, steady union traits along decent computing efficiency. The brushless DC motor is exhibited within Simulink along with the algorithm of PSO is applied in MATLAB. Associating with GA and LQR (linear quadratic regulator) technique, the suggested technique was further effective for the improvement of the stage reaction features like, decreasing the stable-states fault; rising time, settling phase and supreme overshoot in rapidity controlling of a linear brushless DC motor. B. Nagaraj et al (2008) demonstrated the structures of PID controller adjusted to control the DC motor controlled by framework. Nonstop steering technique & Z-N stage reaction technique are the standard techniques having operations that has been likened as well as examined using the intellectual modification methods such as Genetic procedure, Evolutionary program design and optimization of element group. GA, EP and PSO founded alteration techniques have demonstrated their superiority in offering improved outcomes through refining the stable phase physiognomies and operation guides.

Subrata Chattopadhyay et al (2008) established a reduced costing working amplifier founded PID controller having opposite offshoot controlling activity has been defined. Its transferring functionality has been derived thereby being matching to the system previously resultant through different labors. Testing has been done through a procedure plant equivalent and applied within the system of voltage controlling of a DC generator.

Luyben et al (2011) demonstrated regarding GA a configuration interaction (CI) method; along with its application in PID modification for a live engineering procedure have a closed-loop. In comparison with different established PID alteration techniques, the outcome demonstrates that improved operation may be attained through the suggested technique. Ho W. K et al (2015) established easy formulations for tuning/designing the PI and PID controllers for fulfilling operator-stated gaining margin as well as stage margin. Such formulations are chiefly valuable with regards to adjusting control as well as auto-fine-tuning, in which the controller strictures need to be planned on-line. The outcomes within this research may be utilized for predicting the attainable rising period of the system that has closed-loop, that is beneficial for self-diagnosing a required facet of 'intelligent' controllers. Novel perceptions within the interior prototype controlled designing of the PID controller are offered as well. M. V. Sadasivarao (2016) demonstrated an easy genomic procedure thereby applying it to tune the PID controllers in case of the systems of cascading control. A procedure to select the searching area is suggested with the use of Ziegler–Nichols alteration method. Steadiness and sturdiness principles are guaranteed in the assortment of the searching area, permitting the technique for application towards web fine-tuning. The internal and external loops are adjusted instantaneously, causing the technique appropriate devoid of any disturbance the controlling approach and guaranteeing complete optimum resolution. The summation of primary total mistake values of the controlling reaction is utilized as the factual purpose.

Agarwal et al (2011) suggested Genomic procedures that are strong searching methods founded through the evolutionary codes. A genomic procedure preserves a populace of prearranged resolutions along with guiding the populace in the direction of the optimal explanation. This significant facet of genomic procedure is utilized for stabilizing the upturned pendulum system. The research emphasizes the using and steadiness of upturned pendulum with the use of PID controller having fuzzy logic genomic procedure controller. A huge sum of well-recognized searching methods is there under usage, within the IT business. They suggested a technique for controlling upturned pendulum stable state error as well as over extend with use of genomic algorithmic method. Maruthai et al (2009) demonstrated tuning of a Controller as the procedure to adjust the structures of the designated controller for achieving best reaction for the regulated procedure. In case of several of the controlling issues, an acceptable presentation is acquired using PID controllers. Among the key issues with calculated mockups of tangible systems is that the strictures made use of within these replicas are undeterminable with complete accurateness. The standards of the strictures can alter with time or several outcomes. For such situations, tuning techniques of standard controller go through during attempting too much for generating finest reaction. For overcoming such problems, a Set Point weighting controller using fuzzy logic tuning technique has been suggested. The efficiency of the suggested system is examined via computer replication with the use of SIMULINK program. The replication outcomes founded on fuzzy logic are likened to CC (Cohen-Coon), ZN (Ziegler- Nichols), ZN-SPW (Ziegler – Nichols with Set- Point weighting), IMC (Internal Model Control) and IMC-PID controller reactions (Internal model founded PID). The outcomes of procedure exhibiting flaws along with the significance of controller tuning was exposed with the use of the suggested controlling system. DC motors are gaining broader functionality within the business-like automation, guided automobiles, chemical procedures and so on. Motor controlling for precise locating and rapidity is quite a significant utility in several operations. Important studies were performed over the speed of motor along with positioning control with the use of several controllers.

Hasheem et al (2010) has reported that the control system of DC motor speed based on microprocessor is achieved in an understandable manner. Such a system integrates microprocessor, which is primarily a system having slow data acquisitioning process along with the microcomputer which controls the motor speed. Khanniche et al (2015) has reported the development of the scheme of measurements of digital speed which is further implemented using the microcontroller of Intel 16-bit 80C196 in real-time. This suggests that the measurement accuracy of $\pm$ 0.04% can be obtained based on shaft encoder of 360 pulses/rev DC drive results replacing the loop of digital speed indicates an improvement in the performance of speed control when compared to the traditional DC drive.

Asaad et al (2018) has proposed the circuit speed optimization taking help of the FPGA having embedded RAM. This has then mentioned the circuit of active line repair (ALR) in terms of the specialized circuit which surpasses the imperfections of manufacturing imperfections in the display panels of high resolution. They then discussed the ALR circuit designing along with the speed bottlenecks for the implementation on the FPGA along with the optimization alternatives. The results have stressed on the need to represent data and then match the same to the resources of underlying hardware like blocks of embedded RAM. Lastly, the circuit optimized runs at the clock speed of 63 MHz, attaining the speed up of 40% across the design. Zhiliang Ding et al (2009) has presented the controller of PID that has been used widely in the canal system of automatic water conveyance. But, the PID conventional controller is seen to poor canal conditions adaptability and the canal operating conditions variations.

The PID parameters online self-adapting is another issue when solving the PID controller, hence, fuzzy control gets PID control combined, designing the PID controller fuzzy self-adaptive which is then implemented to the canal operation's automatic control system. When the canal is seen to operates, in terms of the actual conditions of response, the computer would use a fuzzy reasoning, with PID parameters adjustment which is realized automatically.

Meiyu et al (2009) has presented one of the advanced Fuzzy namely the intelligent PID controller that has been applied in the PID controlled hydraulic system of snow removing truck's along with the combination of intelligent fuzzy control. The experiment simulation has proven the feasibility. Gui et al (2011) further reported a reactor of electric-heating that used widely in several chemical experiments, with production process that is fine and special. On summarization of the tuning experience of PID and human operators knowledge into the rules of fuzzy tuning, auto-tuning PID (FA-PID) fuzzy control algorithm has been developed for temperature control of the reactor of electric-heating employing the rules of fuzzy tuning to the real-time PID parameters on-line. Shouzhi-L (2006) has presented practicality and astringency of the PSO algorithm or the particle swarm optimization along with T cell's promotions and the restrain ability of B cells of Immunity PSO Algorithm (IMPSO) which is then implemented to the controllers of PID. It is seemed that the IMPSO turns suitable to leverage the PID control in terms of the simulations which makes the anti-jamming and tracking of IMPSO basing IM PID effective as compared to the ones based on the PSO and on Immunity Algorithm.

Xiao-FengLi et al (2007) has shown the conventional PID controller control quality as used in any control system, as the strategies of fuzzy-PID controller design by using the benefits of auto tuned and fuzzy PID controls along with mutual compensation. Tuning method based on a phase along with the gain margin has been proposed for determining the fuzzy PID controller’s parameters to cope with the new power plant being in the working conditions and frequently changes in the time-varying dynamic nonlinear property. Using the methods of fuzzy inference, the parameters of fuzzy PID are adaptively adjusted on varying system of line and operating conditions that change. This strategy that gets implemented based on a function code on several DCS. The application industrial results reveal the presence of complex systems which can use the strategies of design and has effective control performance. YuzhenSun et al (2010) then presents the system on biological immunity that has immense robustness and the self-adaptability in situation of uncertainty and disturbances with nonlinear PID having benefits of a simple algorithm, faster convergence and small overshoot. This fuzzy immune method is integrated with the nonlinear PID with the control strategy of nonlinear PID control based on the algorithm of fuzzy immune been proposed.

Chunwen et al (2010) has presented the complex system elevator kind having characteristics of time-variance and strong-coupling. For the elevator systems, using the algorithm of traditional PID, adds to the disadvantages of selection of optimal parameters, weak behavior in steady-state, etc., achieving the effects of satisfactory control become difficult. So, they discuss the above theory with the help of the RBF neural network for control object identification giving to BP network, the received Jacobian message and uses the BP neural network's ability of arbitrary nonlinear expression for attaining the PID control parameters optimum combination via studying the system, which then reaches the goal of stable and speedy control. Another representation by Shanmugasundram et al (2009) of the economical driver of high-speed and the converter circuits along with the control strategy of pulse width modulation implemented in Aduc812 versatile micro controller to attaining effective performance. Such results show that the experimental set.

Thus, from the presented literature review it can be concluded about the development of speed controller, it is also aimed at implementing proportional-integral-derivative (PID) theory or logic controller to proceed the controlling of speed and direction of DC motor. So, the next chapter includes the overview of Embedded system with reference to different controllers and processors according to the recent technology trends. Following with the chapter of the design and development of Ethernet Based speed controller for DC motor using ARM cortex.

CHAPTER 3

OVERVIEW OF EMBEDDED SYSTEMS

The embedded system is more like a dedicated system which has been designed to do a specific task amidst a larger system, having the constraints of real-time computing. The above is embedded as the complete device part that includes the mechanical and hardware parts. On the contrast, a computer of general-purpose, like the personal computer has been designed to own the flexibility and map huge application. Several devices can be controlled using embedded systems. Such systems have either the DSPs (digital signal processors) or the microprocessor as the processing cores. The entire prime characteristic, but, is attributed to perform a specific task. As the embedded system has been attributed to do a particular task, optimization of the system has been done for size reduction and also the product cost thereby improving the performance and reliability of the system.

In different ways, reshaping of the embedded systems has been done to determine the way we work, live, and play. The embedded system embeds in various types, where each exhibit distinct characteristics. The Embedded systems shows the type of dedicated computer systems which has been designed to do a task. Generally, the embedded systems both are predictable and reliable. The embedded devices are convenient, dependable and user-friendly. With tremendous evolution, the embedded systems alter the environment at home and in industries. As a matter of fact, the huge application is this domain is the parameters of robotic control such as position and speed controlling and accounts for a huge collection of interconnected embedded systems using several technologies and control process. Range of industries use these embedded systems for the task of process control. Embedded systems as used in industries has been tailored to perform tasks like monitoring pressure, temperature, voltage, humidity, current etc., which can then take significant action.

Embedded systems general definition is devices that are used to monitor, control, or assist the task of machine equipment, or plant. The term “Embedded” shows that these are a crucial aspect of system. In majority of the cases, “embeddedness” could be in the prevalence of something away from the observer. The embedded systems block diagram is shown in Figure 3.1 which explains about the real time flow of the system.

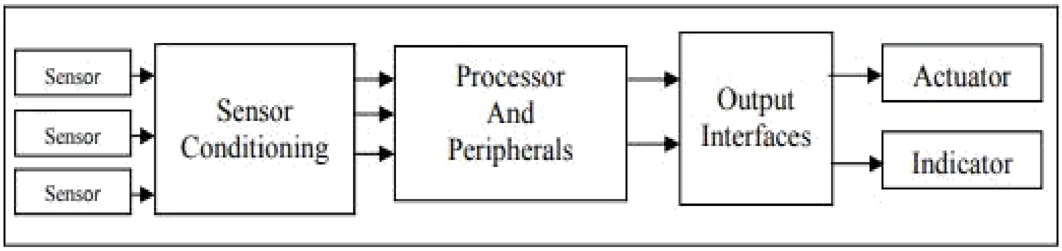

Figure 3.1: A Typical embedded system

3.1 CHARACTERISTICS

Efficiency is seen to have immense importance for the different embedded systems. They have been optimized for code size, energy, weight, execution time, cost, and dimensions. The Embedded systems are custom fit to map constraints in real time; the system in real time reacts to the stimuli from operator or the controlled object given the interval as said in environment. For system in real time, right answers are either wrong or arrive late. Embedded systems are seen to interact with the world external via actuators, sensors and so are typically the reactive systems, such as reactive system appears to be in continual interaction, executing at the pace pre-determined by the environment. Application of embedded systems is single functioned and specific with programs being repeatedly executed. They have generally minimal or zero user interface.

In the embedded system, the software system is embedded within application software, and is vice versa in case of personal computers. Embedded systems very essence is iterative, execution of the embedded system in a step-wise way of embedded program with data stream. Embedded system is seen to have a single build i.e., a single executable file. Here, the operating system does not act as the distinct entity. Just the needed quantity of the software is seen to assist the software of application. A crucial need of such systems is lower the consumption of power, space and cost. This is attained by integration of functions in the chip of CPU. The programming embedded systems are a major discipline with demands as worked by the developers of embedded systems in technology. The above range between the device of low-level hardware, techniques of debugging and compiler technology, to core real time working of operating systems and applications multithreaded.

Featured embedded devices must run applications of multimedia which demands higher computational power and has constraints of low consumption of energy. The world that is embedded appears to be mature and having computing universe's steady segments. Any of the embedded devices can be reshaped to be useful, flexible, and further less expensive when tailored to be intelligent. Conventionally, the embedded devices are hardware-centric, and the software embedded is simple and designed carefully for optimization of performance and lowering the footprint of memory. But, higher than 70% of cost of complex system development like the communication system and the automotive electronics gets attributed to development of software. The above percentage is seen to constantly rise.

Robotics today is one of the most powerful domains having immense interest in carrying out complicated tasks like the hardware assembly. To promote the control of complex systems like the automobiles that are drive-by-wire and aero planes that are fly-by-wire, the networked and the embedded computer systems having enormous software and hardware components are required. The embedded systems that performs task in a given period of time are deemed as the real-time embedded systems. The embedded systems development has been done using assembly languages. But, because of presence of cross compiler, major developments are done in languages like ‘C’. The embedded systems are seen to be omnipresent, thereby playing crucial roles in today's world.

Conventional computer architecture or the one components of computer engineering emphasize on the fundamentals both software appropriate for the computing of general purpose. But, there exists the growing realization of need of embedded systems of special purpose necessitating a different educational focus as compared to the computing of general purpose. Such a microcomputer is the embedded chip, that is used typically for the control applications, core emphasis has been made on the protocols of communications with device's like CAN, SPI, RS-232, I^2C. In the same way, for the non-digital interactions, a different emphasis has been done on the conversion of digital-to-analog and analog-to-digital as multiple applications of control are time-critical. Next emphasis is paid on interrupts and time for a small part of the microprocessor applications. Few estimates, higher than 90% of the systems that are microcontroller-based are the embedded systems of special-purpose and not the computers of general-purpose.

Each of the embedded system has been seen in the devices of computing to perform a task. Several applications like VCD player, air conditioner, printer, DVD player, mobile phone, fax machine, etc., are few instances of the embedded systems. Such applications own hardware and a specific processor to map applications specific requirement added with the embedded software that gets executed by all processor for tuning to the needed requirement. One can also call the embedded software as “firmware”. The market of embedded system recorded the area of highest growth since the systems usage in market segment of consumer electronics, biomedical engineering, office automation, data communication, wireless communications, industrial automation, transport, telecommunications, military and more. Microcontroller has I/O lines, memories, interrupts, timers/counters, along with serial communication. Taking help of the microcontroller is of highest advantage, within the leveraged efficiency and reduced hardware. Generally, majority of the embedded control systems has been designed across microcontroller that integrates on the memory of chip program and of data across with peripherals like time or counters, I/O ports and serial communication. Microcontrollers that has been used in various applications, primarily in applications of real time. The product of embedded system is seen to use the microcontroller for performing a single task as the embedded system printer where the microcontroller amidst it is seen to do a single task like data acquiring and printing the same.

3.2 CHALLENGES AND RECENT TRENDS IN EMBEDDED SYSTEMS

The system of embedded software has been defined as the computing system which interacts within physical world. However, this is the incomplete definition since every system of software would run up once and can interact in the physical world. Significantly, what we mean to say is that the system of embedded software attains the requirements being non-functional, that concerns the interaction of the system in physical world. These embedded systems have components of software programmable that interacts the dedicated hardware. These systems appear to be the software specific application systems, of hardware and the channels of communication that has been tailored to perform a particular task. These generally are the larger system part and at times, the candidates for the SOCs, realization of system-on-a-chip, software that gives flexibility and features and performance of hardware. Apart from the performance and the flexibility, several metrics consisting of the cost, reliability, weight, size, and power constraints. Few applications in the industry of IT-systems, continually alters specifications, and further the success relies on the time-to-market. The above accounts for the improved and suitable model of process development that recognizes the product life cycles along with the integrated and an efficient path of software and hardware development.

3.2.1 Technology challenges

The Embedded systems are a core part of the today's world. It could be the cell phone, music player, the smartcard, and the router, or the automobile electronics - such systems are touching and change the modern lives which are something like never done before. The technology of embedded systems is the intelligent products core like device's consumer electronic devices along with the automotive products. The above is the yet-evolving class of product that calls for other class technology as microprocessor software, analog, memory, and the system of mixed signal, and the reprogrammable circuits. Challenge of embedded Systems in recent years is to detect the hardware virus appeared in the design. The designer of hardware is inserted in the hardware trojans of few chips which has been manufactured. And the challenge is testing all manufactured chips and the classification of chips that get Trojan infected and chips that are Trojan-free. To attain the purpose, more than one of the following techniques of Trojan-detection has been used.

i. Functional test: Special patterns of functional test have been created for Trojan activation and then observe the output effect.

ii. Side-channel analyses: The power consumption, delay, and the chip parameters has been analyzed and the Trojan impact get distinguished on the said parameters from variations of process.

Teams need to submit the initial report based on the trojans detection of possible ideas. The system design's universal challenge is the system construction and behavior get predicted. In these embedded systems, the system behavior interesting aspects encompass the functionality and the properties of execution and reaction like resources and timing consumption. For the illustration sake, concentrating in the timing following. For such a purpose, the system behavior notion which it includes, along with computed values along with times of availability of the values computed. In case other dimensions being non-functional of behaviors have interest, like power consumption, then the arguments similar are made.

Another challenge in the design of embedded systems universally is the components construction which has the robust behavior in perturbations presence. While we understand robustness for majority of the artifacts of physical engineering, they are heard rarely in software connection. The above is due to the idealization of the computer programs as objects of discrete mathematics in terms of the perspective as advocated in the subject of computer science till 1960s. In case the program has been studied in terms of the object of discrete mathematics, then the correctness is form of the Boolean notion and set up by proof: either the program would satisfy the requirements in cases it fail to and the programs prevalent view as the partial discrete functions on states and values that account for tremendous successes: and enables the paradigms of computing science along with complexity, computability, and semantic theory.

As seen in computer science, unlike the face of discipline engineering, often give up the sight of fact that the software system of mathematical representation is a model, and where the actual system being physical, that gets executed on the platform that is imperfect and interacts within the environment that is unknowable. The programs realizations are ultimately the Boolean illusion physically shattered. The programs that are mathematically correct, one need to prefer to choose the way that appears to be there environment and platform which deviates from expectations that are nominal and this can be because of failures and resource limitations, simple erroneous attacks or specifications incomplete. To an extent, such an observation guides the robust design for the software that is non-embedded, for instance, by attaining the checks of system if the value of input is within the range expected. Also, one program can have tolerance more than other and be equivalent functionally against the potential of larger class attacks, etc. Yet the sharp view of Boolean incompleteness turns apparent in cases of the embedded programming, and here computing maps the demands of physical world.

3.2.2 Recent technology trends

The industry of embedded systems dates to the time of microcontroller’s invention and from that time it emerged victorious from being designed to aid applications of machine control to other verticals with the communication convergence. For past few years, enormous attention is given to the domain of embedded systems for power processing and functionality.

Table 3.1 Principal chip improvement categories

Trend	**Example**
Integration Level	Components/chip, Moore's Law
Cost	Cost per function
Speed	Microprocessor Clock Rate, GHz
Power	Laptop or Cell phone battery life
Compactness	Small and Light weight products
Functionality	Non-volatile Memory, Imager

The embedded computing is the definite trend that helps migrate to 32-bit and 64-bit and from single processors to the multi-core processors. These systems map their goals of performance, including constraints of real-time via the fusion of hardware on special-purpose and components of software designed to map system requirements. The principal chip improvement categories are given in above Table 3.1.

Development of semiconductor technology makes an impact on the processor skills which can be seen through computer architects being obliged to circuit technology for the gains since it offers encouragement for the revolution as it decreases the denseness and provides more transistors. CMOS technology carried out Moore's law for 2 decades. Computer architects have not just used these faster transistors providing a superior clock-rate, but they have properly used the increasing number of transistors as well. Every linear shrink provides a linear enhancement in the clock rate along with the quadratic growth in number of transistors.

Such enhancements occurred due to the skills of industry in shrinking geometrical features sizes appearing in the integrated circuits. Key movement and an important state for enhancements is integration level which can be shown as Moore's Law that describes number of functionalities per chip and CPU performance (MIPS) doubling once in 18-24 months. Gordon Moore made this estimation in the year 1965 before co-finding Intel and it has been true till 2002 and likely at least 10 years after that, as per the estimation of ITRS (The International Technology Roadmap for Semiconductors).

Embedded system is complicated as it comprises a considerable number of electronic instruments which are linked to actual world by sensing and actuating devices. System is varied as it is classified through the synchronicity of numerous factors like microcontroller and Digital Signal Processing along with the analog factors like A/D and D/A converters, receivers, sensors and transmitters. Previously, system design effort emphasized on such hardware parts and left software designing process for later in the execution phase. The new software technologies are essential for the time coming ahead as the complications are growing. Information technology became increasingly significant for the new automotive applications and services. The costs associated with information technology in care manufacturing are extremely high and will keep growing in the coming time.

New embedded system can be classified through the increasing software complications in which embedded software overpowers the development cost and routine. Linux introduces with the possibility of open multi-vendor platform with the increasing software base and hardware assistance. Increase in usage of Linux in the embedded systems in last couple years is incredible. Success of Linux in server or desktop field in past couple years was the center of focus in which most passionate supporters of Linux made efforts to loosen the strong hold of set-up operating systems like Windows. Comparatively, in embedded marketplace, Linux is going in the direction of world domination. In embedded operating system UNIX, graphic display management is divided between X server that is aware of the hardware and provides an integrated interface to the user programs.

3.3 ARM PROCESSOR TECHNOLOGY

Because the ARM processors are easy and uncomplicated, they are on the top in mobile and embedded electronics market. ARM processors constitute for 90% of all the embedded processors and are globally used in the consumer electronics which comprises of tablets, mobile devices, digital media, hand-held game consoles, calculators, music players and computer peripherals like routers and hard drives. ARM microprocessor range offers the answers for open hardware platforms operating complicated systems for wireless, imaging applications, customer, real-time systems for mass storage, embedded, automotive, industrial, networking applications, smart cards and single inline memory (SIM) modules.

ARM is 32-bit reduced instruction set computer (RISC) also called instruction set architecture (ISA). It was termed as advanced RISC Machine and prior to that, Acorn RISC Machine. Well-known ARM processor families were built which comprised of ARM7, ARM9, ARM11 and Cortex. Official Acorn RISC Machine project began in October 1983. VLSI introduced first ARM silicon in April 1985. First actual production systems called ARM2 were access the following year. Actual purpose of ARM-based computer was accomplished in the year 1987 as Acorn Archimedes was released. ARM2 featured a 32-bit data bus, a 26-bit address space and twenty-seven 32-bit registers. ARM2 was a basic but helpful 32-bit microprocessor and had just 30,000 transistors. It resulted in the low power usage. ARM3 came after that which was generated using 4 KB cache and it enhanced the performance. From 1995, ARM architecture reference manual is the key source of authentication on ARM processor architecture and instruction set. There have been developments in architecture in all these times which began from Cortex series of cores where three "profiles" were described: "Application" profile: Cortex-A series, "Real-time" profile: Cortex-R series, "Microcontroller" profile: Cortex-M series. For the proper, faster, and basic design, ARM implementation was hardwired with no microcode. ARM architecture properties comprise of Load/store architecture, Uniform 16 × 32-bit register file, fixed instruction width of 32 bits for simplifying the decryption and pipelining.

To make up for the more straightforward design, contrasted and impermanent processors extra design highlights were utilized: conditional execution of most guidelines, lessening branch overhead and making up for the absence of an indicator. Number-crunching directions modify condition codes just when wanted, as 32-bit barrel shifter which can be utilized without execution punishment with most math guidelines and address counts, incredible ordered tending to modes, interface register for quick leaf capacity calls, and straightforward, however quick, 2-need level interfere with subsystem with exchanged register banks. There are exceptional components for tending to coprocessors in the ARM architecture. In ARM-based machines, fringe devices are generally joined to the processor by mapping their physical registers into ARM memory space or into the coprocessor space or interfacing with another device (a bus) which thus connects to the processor. All advanced ARM processors incorporate equipment troubleshooting offices utilizing JTAG support, without them, programming debuggers could not perform fundamental activities like ending, venturing, and break pointing of code beginning from reset. The ARMv7 architecture characterizes fundamental investigate offices at a design level. These incorporate breakpoints, watch focuses, and guidance execution in a "Troubleshoot Mode", comparable offices were likewise accessible with installed ICE.

Thus, further in the chapters it is shown how to design and develop Ethernet based speed controller for DC motor using ARM CORTEX processor which help in controlling speed and direction.

CHAPTER 4

DESIGN AND DEVELOPMENT OF ETHERNET BASED SPEED CONTROLLER FOR D.C. MOTOR USING ARM CORTEX PROCESSOR

4.1 INTRODUCTION

The electrical motors usually utilized in industrialized purposes are dissimilar from one another structurally. It is utilized for converting the electric power, delivered through the controller to motorized energy for moving the load. There are 2 kinds of motors, DC and AC. DC motor is a power actuator machine that transforms direct power electric energy to rotating mechanical energy. Due to their resourceful characteristics like great rotation, speed controlling across a broad extent, movability, well-performed speed-rotation features, along with adaptableness with several kinds of controlling techniques, DC motors are yet broadly utilized in numerous industrial uses, counting electric trains, picking, placing, packing the objects robotic manipulators, steel rolling mills, machine tools, etc. DC motor essential parts are displayed in Figure 4.1.

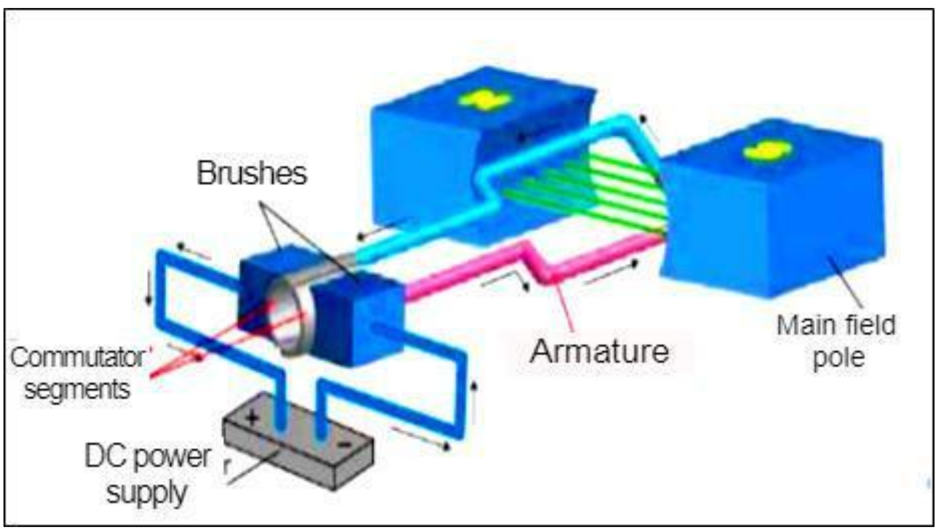

Figure 4.1: Diagram of DC motor

PID logic controllers have certain benefits in comparison with different controllers like the ease of control, along with the capability of designing controlling system devoid of the requirement for precise and exact mathematical prototype of a compound and non-rectilinear structure. Therefore, the current investigation regarding designing as well as progress of PID logic controllers for DC motor speed function. An alternative of the wound field DC motor is the universal motor. The primary commutator-kind DC power motor having the ability to be applied practically application was designed by a scientist from Britain, called William Sturgeon during 1832. After work done by Sturgeon, a commutator-kind DC electrical motor constructed intended for industrial usage was created by the American Thomas Davenport along with being untested during 1837. Even though various of such motors were constructed thereby being utilized for operating tools like a printing press, because of the elevated price of main battery power, the motors were economically unproductive thereby causing Davenport to go broke. Numerous designers trailed Sturgeon to develop DC motors yet each of them stumbles upon the similar price matters with prime battery power. No electrical circulation had been industrialized during that phase. Like sturgeon’s motor, no real-world profitable marketplace existed for such motors. The DC motors are broadly utilized in the adjustable speed functions because of the simplicity of speed control. In closed-loop structure, the speed may be sustained constantly through regulating the voltage of the motor terminal. DC motors that are smaller function at reduced voltages that cause them simpler for interfacing with controlling electronics. DC motors are usually utilized wherein exact speed regulator is essential, as within computer disk drives or in recorders of video cassette, the axles inside CD, CD-ROM drives, as well as apparatuses inside office merchandises like fans, laser printers and photocopiers and such, the thorough description of DC motors is demonstrated in several books. The DC motor’s key benefit is its reduced upkeep, great effectiveness. As the DC motors are utilized particularly in maintenance of speeding functions, the speed is among the significant procedure factor which is to be observed and regulated within commerce.

4.2 PRINCIPLE

The principle and block illustration of the DC motor speed control system based on ARM processor is exemplified. The block diagram comprises an LM3S9B96 controller based on ARM processor, DC motor having optical sensing component, frequency to voltage (F/V) converter along with a personal computer. The optical encoder recognizes the motor's speed thereby converting it to a sequence of TTL attuned beats. Frequency is produced in proportion with the motor's speed. This frequency is transformed into proportionate voltage through F/V converter. Microcontroller obtains the voltage via inbuilt 12-bit A/D converter. This voltage within digital structure is transformed back towards consistent frequency according to below equation:

$$V_{out} = f_{in} \times 2.09 \times \frac{R_l}{R_s} \times R_t \times C_t$$

where, V_{out} , f_{in}, R_l, R_s, R_t and C_t represents the F/V converter's output voltage, signal frequency, load resistance, series resistance, resistance of the transmission line and capacitance of the transmission line respectively. produced from optical encoder, this frequency is transformed to speed in unit of rpm through this equation.

Speed = (Frequency *60 seconds)

Rpm = (Frequency * 60) rpm

In case of the optical encoder utilized, single beat is produced in case single full rotation that is changing to voltage through the use of the frequency towards circuit of voltage driver [IC LM331] for being attuned to microcontroller built in ADC. The calculated speed of the motor has comparison to the established rate for obtaining the fault and this fault accompanied by change-in-error is put on the PD, PI and PID algorithms. The controller yields the controlling function consistent with the error. The microcontroller thus puts on this controlling function, in the voltage form, in the motor via PWM generator. The ON period of PWM wave fluctuates regarding fault signaling. In case the loss/gain of the signal is greater, then ON period will be greater as well as other way around. From now, the power put on the motor via actuator will fluctuate with wave of PWM. This process is reiterated until the motor grasps the preferred speed. Therefore, the speed of the motor is organized at the preferred rate. The particulars of specific blocks of the block illustration have been discoursed in the following segments.

4.3 HARDWARE FEATURES

The whole system hardware comprising LM3S9B96 expansion board, Driver circuitry, DC motor having sensor of speed, Relay Circuitry along with a PC are created as well as invented domestically within the current research. The construction of the system of the suggested ARM founded speed controlling structure is demonstrated in Figure 4.2. The subsequent segments define the facets of hardware of the speed controlling system of the DC motor.

Figure 4.2: Photograph of ARM Cortex (LM3S9B96) board Unit

4.3.1 DC motor and speed sensing unit

DC motor speed sensing unit utilized in current investigation are talked about in this segment. Most electric motors, in which electromagnetic torque is used, depend on the energy transformation from electrical to attractive then to mechanical energy. A basic segment of the control framework is the actuator. The actuator is the primary framework segment to really move, changing over electrical energy into mechanical movement. The most widely recognized sort of actuator is the electric motor, which is electromechanical energy converter, changing over electrical energy in to mechanical energy. Motors are delegated either DC or AC, contingent upon the sort of intensity they use. Although the DC motors are much costly than AC motors, they become common in apparatus control in light of the fact that their speed and torque are anything but difficult to control with the straightforward hardware. DC motor highlights speed controllability over a wide range and even heading of pivot can be changed whenever to meet new conditions.

Table 4.1: DC motor specifications

Description	**Value**
Rated Voltage	12VDC
Rated Current	500 mA
Maximum Speed	3000RPM
Torque	50 gm-cm
Weight	150g

Littler DC motors regularly work at lower voltages (for instance, 5V circle drive motor), which make them simpler to interface with control hardware. The DC motor utilized in the current investigation are provided in above Table 4.1.

Optical encoder is one of the broadly utilized speed sensors. This non-reaching type sensor comprises of an optical source on one side, and a finder on the opposite side. The opened circle, associated with the pole of DC motor, turns between the optical source and finder, along these lines delivering optical slashing. The aftereffect of this is a yield of heartbeats with a rate relative to speed and the quantity of openings on the circle. The optical source is typically a LED or an infrared transmitting diode. The identifier can be a photograph responsive semiconductor gadget, for example, a photodiode, a phototransistor, a photograph Darlington, or a photograph FET. The benefit of these opto-interrupters is that, fine speed control goals are effectively acknowledged by only presenting various spaces on the plate.

These opto-interrupters are called as opened optical switches. In the present investigation, the optical encoder is planned with the opened optical switch with one gap contains on circle for estimating the speed of the DC motor. The circle is associated with the pole of the DC motor. As the DC motor runs, the circle pivots between the optical source and indicator of opened optical switch. During the pivot of the plate, at whatever point opening shows up between the optical source and the locator, the light is slashed intermittently. Thus, a train of TTL perfect heartbeats whose recurrence is corresponding to the speed of the DC motor is created. Since, a circle with single opening is utilized; one heartbeat is created for one upheaval. These heartbeats are bolstered to the F/V converter, to change over the recurrence of the beats into the relating simple voltage.

4.3.2 ARM Cortex Processor (LM3S9B96) board Unit

ARM processor is the fundamental spine of the control framework in current investigation. This sets up correspondence with outside gadgets to trade data with remote gadgets, produces PWM sign to control actuators and A/D change task to change over simple flag in to advanced structure for preparing. The engineering of ARM processor is talked about. It assumes significant job in information securing, estimation, show, record and produces control activity to the procedure under scrutiny. The processor is utilized to gauge voltages and control the DC engine speed. ARM Cortex LM3S9B96 application explicit board has been utilized. It is an independent board for LM3S9B96 microcontroller. It has 60MHz precious stone for framework clock and 32 KHz gem for RTC. It has control on reset circuit with MCP130Tbrownout observing chip and power decoupling capacitors. All assets inside LM3S9B96 are very flawless, and it is the most appropriate to learn and think about claiming, if client can learn and comprehend the uses of all assets inside MCU well, the client can alter, apply and create numerous amazing applications later on. Equipment arrangement of LM3S9B96 incorporates the important gadgets inside only one MCU, for example, USB, ADC, DAC, Timer/Counter, PWM, Capture, I2C, SPI, UART, and so forth. The photo of ARM Cortex board.

In current investigation, UART, PWM, ADC and Ethernet highlights of the controller are empowered by calling the comparing API framework calls, control sign will be gotten from the remote PC through Ethernet channel of the controller. As indicated by these sources of info PWM sign will be produced to control the speed of the DC engine. The speed of the engine is estimated utilizing F/V converter, whose yield is associated with the controller’s inbuilt 12-bit A/D converter to give advanced identical voltage. After that the examples are sent to PC through Ethernet correspondence, the presentation of the framework is checked with PID calculation. The Ethernet information transmission has turned out to be imperative to the general registering technique in mechanical and business applications. In PC, the example esteems are perused by utilizing Ethernet correspondence by executing TCP/IP attachments in C# programming language in ASP.Net. The examples are put away in MS-Access information base document, by utilizing record the board library works in .NET casing work in PC. Plots are additionally drawn with similar sign for client adaptability, straightforward and perception. The speed of the DC engine is estimated and contrasted and given info (examined) on PC as graphical portrayal with the assistance of ASP.NET programming. The exhibition of the framework is tried with different info signals.

4.3.3 Pulse width modulation (PWM)

Speed of DC motor relies upon the current through its armature curl. With a field curl motor, the speed can be changed by either shifting the armature current or the field current. By and large it is the armature current that is differed. In this manner, speed control can be accomplished by controlling the voltage connected to the armature. Since in the current examination, the control signals for DC motor speed control are exuded from the PC, in such cases a strategy known as heartbeat width regulation (PWM) is commonly utilized. This fundamentally includes taking a consistent DC supply voltage and cleaving it with the goal that the normal worth is shifted. Subsequently PWM is utilized to control the normal voltage connected to the armature.

PWM or pulse-width modulation wave is defined to be an analog signal which is transferred between two preset limits. The switching duration in the signal is regulated by the reference signal (D/A converter output) and it decides the mean or average power delivery to the motor by means of actuator. With increasing voltage, the PWM width or duty cycle is magnified as well. This alternatively amplifies the DC motor speed. On the other hand, decreasing voltage is proportional to the decreasing PWM width, and this reduces the DC motor speed. The PWM signal has proportional connection with the reference signal, and this is again proportional to the computer output.

PWM is the internal characteristic of LM3S9B96 controller that can be activated by inducing the contextual API system calls; the pulse width can be regulated by fixing the on/off time. PWM or pulse-duration modulation (PDM) method is frequently utilized to control the power to internal electrical tools, and is practically modified with the help of new electronic switches. This current empirical work shows the DC motor speed regulation PWM duty cycle signals to be emanated from the remote computer. This research oriented PWM tool is primarily started by referring to API system cells. It is about using a consistent Direct Current provision voltage as well as cutting it to differ the average value. Pulse-width modulation wave is defined to be an analog signal which is transferred between two preset limits. The switching duration in the signal is regulated by the reference signal decides the average power sent to the motor with the help of actuator. Different duty-cycle of the pulse-width modulation can regulate the motor speed as well.

4.3.4 JTAG interface

ARM Cortex-M3 has JTAG as an internal structure for debugging the application as well as for burning the .exe in to the controller PROM/EEPROM/SDROM. This research uses JTAG it's for debugging the application programming code as per the statement with the help of establishing the set points as well as the break points on various schedules. The idea is tracking software bugs as well as hardware feedback signals so that processor registers position or materials can be monitored.

4.3.5 Ethernet controller

ARM Cortex-M3 exists Ethernet like an internal structure for communicating with outer world with the help of TCP/IP protocol suite, by means of LAN connection. The Ethernet Controller satisfies IEEE 802.3 particulars as well as puts forth support to 10BASE-T and 100BASE-TX benchmarks and critical points. This research shows Ethernet for establishing interaction with remote computer to get the control signals so that the motor can regulate and return the personal computer speed of the motor with respect to user's visualization.

4.3.6 Analog to digital converter (A/D)

Analog to Digital Converter (A/D) is an in-built structure for sampling and converting a constant amount to a discrete time presentation digitally. APB block deliver the fundamental clocking for the A/D converters. Every converter includes a programmable divider. For separate estimation like an electronic tool to convert an analog voltage or current signal to a digital counterpart which is proportionally associated with the intensity of the current/voltage, an analog to digital converter is used. The Frequency to voltage converter (F/V) converter output voltage is received in the form of an analog signal. This analog signal is unable to process with the controller therefore it needs to be digitally converted. So, these signals are provided to the A/D inputs of the controller that can turn the analog input signals into digital signals. These resultant digital signals are transferred to the remote computer for visualizing on GUI window as fixed on PC for controller's usage to compute mistakes and improve.

4.3.7 Frequency to voltage converter

The sense unit results in pulse train in proportional connection with the number of motor rotations, these pulses are not able to get or estimate by means of controller appropriately although like an interrupting signal due to more number of pulses. A fixed circuit (frequency to voltage converter) has been set for measuring the pulses obtained by the sensing unit and transforms it to equal voltage levels. LM331 design the frequency to voltage converter, which is a monolithic integrated circuit obtained from National Semiconductor and it is programmable on 8-pin DIP. For converting the frequency of the pulses from optical encoder into respective analog voltage, LM331 gives an output voltage. This output voltage is proportional to the input frequency that gives zero output when it is at zero input frequency. Figure 4.3 shows the internal circuit of the F/V converter. Three fundamental parts are included in the LM331: an input amplifier alongside a built-in hysteric which is a charge pump frequency for converting voltage, and a functional amplifier/comparator that has versatility along with a non-committed output transistor. The primary step acts as a differential amplifier to drive the positive reaction flip-flop circuit. A frequency signal is implemented to the charge pump input. The charge pump comes after the input stage. The frequency is converted into DC voltage by the charge pump. For doing this, a timer capacitor, an output resistor, as well as an integrating or filter capacitor is needed. The voltage coming at pin1 is the same as the frequency input given at pin 6.

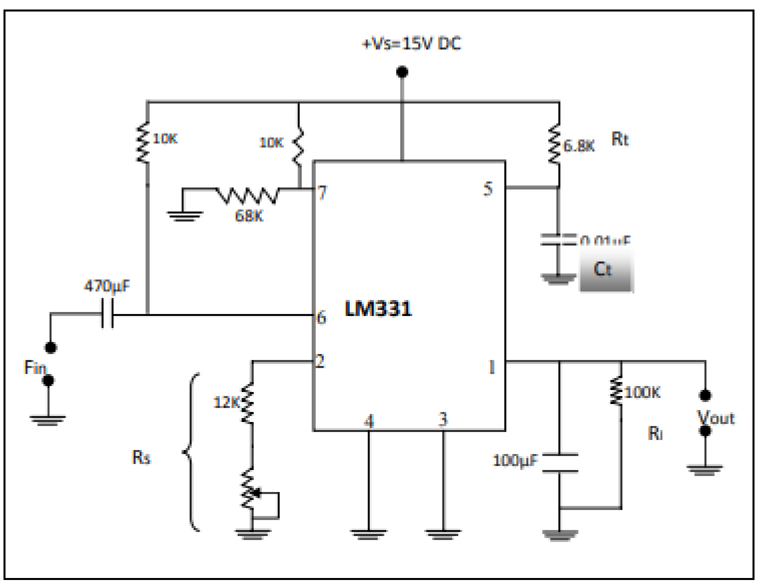

Figure 4.3: Frequency to Voltage Converter circuit diagram

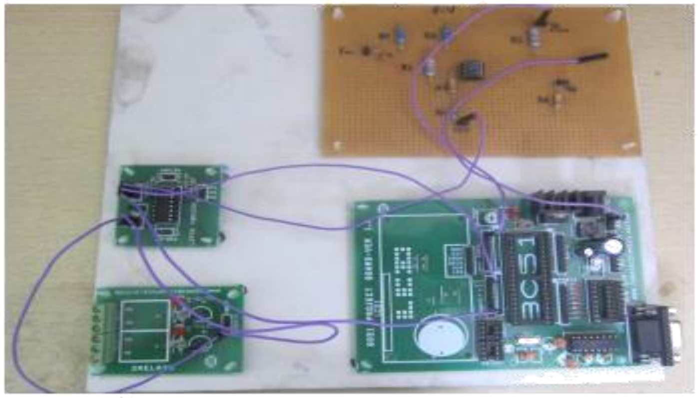

Figure 4.4: Frequency to voltage converter and Driver circuit

4.3.8 Driver circuit

Microcontroller will not be able to connect to a motor in a direct way as it will not provide enough current for operating the DC motors. As a current amplifying tool, motor driver can be a switching device as well. It gets the input signals from microcontroller to result respective motor output. Figure 4.5 gives an elaborated driver circuit program. L239D is a motor driver IC and two motors can be driven at the same time. It's a dual H-bridge motor driver IC. The first H-bridge can drive a DC motor in a bidirectional way. L293D IC is a current amplifying IC because the sensor output cannot drive the motors on its own, therefore L293D is utilized. L293D comprises of a 16 pin IC with two pins that must be set high all the time so that both H-bridge can be activated. Figure 4.4 is the presentation of driver circuit.

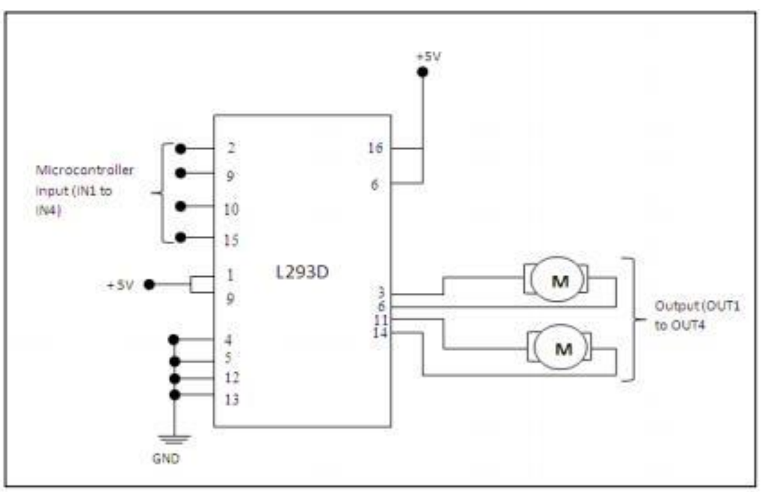

Figure 4.5: Driver circuit diagram

This empirical work uses the output of the PWM signal to be associated to the DC motor by means of the L239D driver circuit for controlling the motor, the Pulse-width modulation signal is sent through driver circuit for securing the controller board from the back EMF resulted by the DC motor in the duration of forward as well as reverse directions. The controller signal will be increased by the driver circuit and this signal is not able to drive the motor, therefore the motor will be energized.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

The testbench framework developed after the proposed design tests all the hardware interfaces efficiently and helps in scaling the health of the board. With the help of developed ethernet module, this current research shows the design of the control system performance with respect to the above-mentioned control application. This is studied in terms of set points as well as step variation examination factors. The most prominent aspect of study outcomes of the developed control system is described in the following:

ARM processor is the most useful one as it has RTC as well as PWM as built-in characters. DC motor speed control system gives in that the PID logic controller showed the most optimal execution when all these experimental conditions are preserved. The PID generated ± 0.28 RPM control with respect to a step size of 3000 RPM. So, PID is the most useful option for DC motor speed control implementation. The inferences from this study are as follows: The ARM-oriented DC motor speed control with the help of PID logic shown here generates a better performance in a dynamical way in comparison to another present microcontroller dependent DC motor speed control. The simplistic design with flexible aspects of the PID controller is the major plus point. The implementation of ARM-oriented controller as a programmable controller to drive is effective and generates the underlying benefits: The hardware conformation to control data accumulation is decreased as ARM-controller includes 12-bit A/D converter and PWM generator as an in-built feature. As a result, highly accurate outcomes in terms of calculation are seen alongside the PID control. Keil4 IDE using JTAG debugger can debug as well as simulate the embedded 'C' language Program Code analysis. Controlling program accumulated in 256 KB of flash ROM of microcontroller, or external interfacing memories, as well as DC motor speed exploration specimens, are transferred to a remote computer for storing in the database. Embedded ‘C’ language programs are easy to execute by skipping the issues engaged to get the simple ‘C’ and Assembly languages. The ability of standard Visual Studios 2010 alongside Origin 6.1 packages is utilized to control, display as well as represent graphically.

External issues cannot affect the third order PID equation as it showed better execution over the first and second order equation of PID when it comes to controlling DC motor speed.
Briefly, the design-making, as well as the utilization of PID logic control, is not tough or costly in comparison to other control algorithms. The most optimal benefit of the current control design is that the standards of PID controllers aren't mandatory to be adapted or designed with speedier feedback. Simple scheduling the system output is enough for getting it. Maximum industry-based procedures use PID control technique due to two major elements; it's a simple architectural aspect alongside the famous Ziegler-Nichols tuning algorithmic development whereas the other cause is the decreased number of standards or criteria for tuning. This PID logic is useful for every aspect in association with system execution.

5.1 FUTURE SCOPE

The information generated from the microcontroller design, devising and application, fabrication as well as study of PID logic controller with respect to DC motor speed controller systems, the recommended empirical evidence is described in the following for futuristic studies. Application of current controllers on high-end microcontrollers with minute OS. Work of suggested controllers is researched to study the set point differences, load variations, influences in terms of random noise and so on. Implementing SBC (single board computer) by means of important software as a tiny Operating system to regulate D.C motor speed. To implement fuzzy logic control for DC motor speed control by using a microcontroller and to carry out the above-mentioned studies. Development of a self-learning (auto-tuned) fuzzy control algorithm for using in the computer as well as a microcontroller with respect to process control terms. Designing the fuzzy logic controller as well as apply on FPGA/CPLD chip with the help of VHDL. It's to be utilized as dedicated hardware (fuzzy single chip) in terms of process controlling usages. Designing and studying the implementation of the above controllers to other procedure control system like DC motor positional aspect as well as AC motor and Servo motor speed control and so on.

REFERENCES

1. T.A. Henzinger, E.A. Lee, A.L. Sangiovanni-Vincentelli, S.S. Sastry, and J. Sztipanovits. Mission Statement: “Centre for Hybrid and Embedded Software Systems”, University of California, Berkeley, 2002.
2. Seungwan Ryu, Byunghan Ryu, MyyoungkiJeong, Seikwon Park, “PI-PD controller for Adaptive and Robust active queue management for internet congestion control”, Society for Computer Simulation International.vol. 18, pp. 437-458, 2015.
3. ZhuoRuanYuzhang Han Jianguo Han, “Real-time Reconfigurable Micro-system Based on FPGA and CPLD For Dual-mode PID Control Through Back propagation Neural Network”, 2011.
4. Jen-Yang Chen “An Integration Design Approach in PID Controller”, IEEE, pp. 901-907, 2009.
5. Jianxin Tang, “PID controller using TM320C31 DSP with on-line parameter adjustment for real time DC motor speed and position control”, IEEE Int. Symp. On Industrial Electronics, Korea, vol. 2, pp. 786-791, 2011.
6. M.H. Moradi “New Techniques for PID controller design”, IEEE, pp. 903-908, 2013.
7. Yun Li: KiamHeong Ang, Chong, G.C.Y. “PID control system analysis and design” Control Systems Magazine, IEEE vol. 26, Issue 1, pp. 32-1, February 2016.
8. Basilio, J.C, Manhes, R.R, Rolim, L G B “Benchmark construction with application to PID Controller design and implementation”, International Journal of Electrical Engineering Education, January 2008.
9. P. Cominos and N. Munro “PID controllers: recent tuning methods and design to specification”,IEEE Control Theory Appl, vol. 149, No. 1, pp. 46-53, 2012.
10. K. Balasubramanian, A.S. Gokhale, G. Karswai, J. Sztipanovits, and S. Neema, “Developing applications using model-driven design environments”, *IEEE Computer*, 39(2): 33-40, 2006.

11. T. Berners-Lee, J. Hendler, and O. Lassila. The Semantic Web. Scientific American, 284(5): 34-43, 2001.
12. Burns and A. Wellings, “Real-Time Systems and Programming Languages”. Addison-Wesley, third edition, 2001.
13. R. Yusof, S. Omatu, and M. Khalid, “Application of self-tuning PI (PID) controller to a Temperature control system”, IEEE Conf. on Control Application, vol.2, pp. 1181-1186, August 2014.
14. Manjunatha Reddy H. K, Immanuel J,Parvathi C. S, P. Bhaskar and L. S. Sudheer, “Implementation of PID Controller in MATLAB for Real Time DC Motor Speed Control System”, Sensors & Transducers Journal. Vol. 126, Issue 3, March 2011, pp. 110-118.
15. S. Liu, P. Merocoelli, and K. Lehmann, “Robust control of a permanent magnet linear motor in the presence of large disturbances”, IEEE Conf. on Control Applications vol. 2, pp. 1301-1306, June 2013.
16. Leehter Yao and Chin-Chin Lin, “Design of Gain Scheduled Fuzzy PID Controller”, World Academy of Science, Engineering Technology, 2015.
17. Visioli, “Fuzzy logic based set-point weighting for PID controllers,” IEEE Trans. Syst. Man, Cybern,- Pt. A, Vol. 29, pp. 587-592, 2009.
18. Chandrasekhar T, Nagabhushan Raju K, 1V. V. Ramana C. H, Nagabhushana KATTE and Mani Kumar C, “Embedded Based DC Motor Speed Control System” Sensors &Transducers Journal. Vol. 121, Issue 10, October 2010, pp. 94-105.
19. Ibrahim Kaya, Nusret Tan, and Derek P. Atherton, “A simple procedure for improving performance of PID controllers”, In Proc. of the IEEE Proceedings on Int. Conf. on Control Applications, Vol. 2, 23-25 June 2013, pp. 882-885.
20. Jose L. Tong and James P. Bobis, “A model for designing digital PID controllers”, IEEE Proc, 9-13 Nov 2012, pp. 1157-1162.
21. Nusret Tan, Ibrahim Kaya, and Derek P. Atherton, “Computation of stabilizing PI and PID controllers”, in Proc. of the IEEE Int. Conf. on Control Applications, Vol. 2, June 2013, pp. 876-881.

22. Jianxin Tang and RulphChassaing, (2017) “PID Controller Using the TMS320C31 DSK for Real Time DC Motor Speed and Position Control, Texas Instruments.
23. Mohamed I. Abu El-Sebah, (2018) “PMSM Position Control with a SUI PID controller”, Electronics Research Institute Electronics Research Institute, Egypt.
24. Rubaai, M. J. Castro-Sitiriche, A. R. Ofoli, “Design and implementation of parallel Fuzzy PID controller for high-performance brushless motor drives: An integrated Environment for rapid control prototyping,” IEEE Trans on Industry Applications, Vol.4, No.4, pp. 1090-1098, Jul./Aug. 2008.
25. Dan Sun, Jung Meng, “A single neuron PID controller based PMSMDTC drive system fed by fault Tolerant 4-switch 3-phase inverter”, Industrial Electronics and Applications, 2006 1ST IEEE Conference on,pp. 1-5, May 2006.
26. Dong Hwa Kim, Jae Hoon Cho, “Design of robust PID controller with disturbance rejection for motor using immune algorithm”, Hybrid Intelligent Systems, 2014. HIS ’04.Fourth International Conferenceon, pp. 444-449, 2014.
27. Saeed Tavakoli, Mahdi Tavakoli, “Optimal tuning of PID controllers for first order plus Time delay models using dimensional analysis”, Control and Automation, 2013. ICCA '13.
28. K. J. Astrom and T. Hagglund, “Automatic Tuning of PID Controllers”, Instrument Society of America, 2008.
29. Hu, B.-G, George, K. I. M. and Gosine, R. G, 2011, “A systematic study of fuzzy PID Controllers-function based evaluation approach”, IEEE Transactions on Fuzzy Systems,09.
30. Manoj Gogoi, “Proportional-Integral-Derivative (PID) controller design for robust stability of arbitrary order plants with time-delay and additive uncertainty”, B.P.U.T, India, 2007.
31. Ho, K.W, Datta, A, and S.P. Bhattacharya, “PID stabilization of LTI plants with time-delay”, Proc.42nd IEEE Conf. on Decision and Control, Maui, Hawaii, 2013.

32. Sujoldzic, S. and J.M. Watkins, "Stabilization of an arbitrary order transfer function with time delay using PI and PD controllers", Proc. of American Control Conference, June 2006, pp. 2427-2432.
33. Sujoldzic S. and J.M. Watkins, "Stabilization of an arbitrary order transfer function with time delay using PID controller", Proc. of IEEE Conf. on Decision and Control, Vol. 45, December 2015.
34. Emami, T. and J.M. Watkins, "Weighted sensitivity design of PID controllers for arbitrary-order transfer functions with time-delay", Proc. of the IASTED International Conf. on Intelligent Systems and Control, November 2008, pp 20-25.
35. L. Mokrani & R. Abdessemed, "A Fuzzy Self-Tuning PI Controller for Speed Control of Induction Motor Drive", in Proc. of 2003, IEEE, Fonf. on Control Applications, Vol. 2, 2013, pp. 785-790.
36. Junji Yoshitsugu & Mutsuo Nakaoka, "Fuzzy Auto tuning Scheme Based on Alpha Parameter Ultimate Sensitivity Method for AC Speed Servo System", IEEE Transactions On Industry Applications, Vol. 36, No. 2, March / April 2010.
37. Patricia Melin and Oscar Castillo, "Adaptive Control of a Stepping Motor Drive Using a Hybrid Neuro Fuzzy Approach", 2011 IEEE International Fuzzy Systems Conference.
38. Vijayakarthick, M., Sathishbabu, S.,Bhaba, P.K, (2017) "Application Of modified repetitive control strategy for DC motor", International Journal of Engineering Science and Technology (IJEST), 3(7), 5500 - 5506.
39. Huang, Y., Yasunobu, S, (2017) "A general practical design method for fuzzy PID control from Conventional PID control", IEEE Transactions on Industry Applications: 969 - 972 vol.2.
40. Hagiwara, T., Yamada, K., Ando, Y., Murakami, I., Aoyama, S., Matsuura, S,"A design method for modified PID control systems for multiple-input/multiple-output plants to attenuate unknown disturbances", World Automation Congress (WAC), 2010.
41. El-Gammal. A.A.A., El-Samahy, A.A,"A modified design of PID controller for DC motor drives using Particle Swarm Optimization PSO", Power

Engineering, Energy and Electrical Drives, 2009, POWERENG '2009, 10.1109/POWERENG.2009.4915157.

42. Yu Lin-ke, Zheng Jian-ming, Yuan Qi-long, “Fuzzy PID control for direct drive electro-hydraulic position servo system”, Consumer Electronics, Communications and Networks (CECNet), 2011 International Conference on 10.1109/CECNET.2011.5768670.
43. G. Sakthivel, T. S. Anandhi, S. P. Natarajan, “Real Time Implementation of a DC Motor Speed Control by Fuzzy Logic Controller and PI Controller Using FPGA”, Sensors &Transducers Journal. Vol. 121, Issue 10, October 2010, pp. 106-120.
44. S. M. Giri Rajkumar, Atal. A. Kumar, N. Anantharaman, “Application of Genetic Algorithm for Tuning of a PID Controller for a Real Time Industrial Process”, Sensors &Transducers Journal. Vol. 121, Issue 10, October 2010, pp. 56-67.
45. Gopalakrishna G, Sivakumaran N. and Sivashanmugam P, “Enhancement of Heat Exchanger control Using Improved PID Controller”, Sensors & Transducers Journal. Vol. 107, Issue 8, August 2009, pp. 144-156.
46. G. J. Silva and A. Datta, “New results on the synthesis of PID controllers”, IEEE Transactions on Automatic Control, 47, 2, 2012, pp. 241-252.
47. C. C. Hang, K. J. Astrom,, and W. K. Ho, “Refinements of the Ziegler-Nichols tuning Formula”, IEEE Proceedings-Control Theory and Applications, Vol. 138, No. 2, 2011, pp.111-118.
48. P. J. Gawthrop, and D. E Nomikos, “Automatic tuning of commercial PID controllers for Single-loop and multi-loop applications”, IEE Control Systems Magazine, January, 2010, pp. 34-42.
49. M. B. B. Sharifian, R. Rahnavard and H. Delavari, “Velocity Control of DC Motor Based Intelligent methods and Optimal Integral State Feedback Controller”, International Journal of Computer Theory and Engineering, Vol. 1, No. 1, 2009.
50. Asim Ali Khan, Nushkam Rapal. “Fuzzy PID Controller Design Tuning and Comparison with Conventional PID Controller”, In Proceedings of the IEEE International Conference on Engineering of Intelligent Systems, 2016, pp.1-6.

51. Mehdi Nasri, Hossein Nezamabadi-Pour, and MaliheMaghfoori, “A PSO-Based Optimum Design of PID Controller for a Linear Brushless DC Motor”, World Academy of Science, Engineering and Technology, 26, 2007.
52. B. Nagaraj, S. Subha, B. Rampriya, “Tuning Algorithms for PID Controller Using Soft Computing Techniques”, IJCSNS International Journal of Computer Science and Network Security, Vol. 8 No. 4,April 2008.
53. Subrata CHATTOPADHYAY and Satish Chandra BERA, “Design and Testing of a Low Cost PID Controller Combined with Inverse Derivative Control Action and Its Application in Voltage Control Systems of DC Generator”, Sensors & Transducers Journal. Vol. 87, Issue 1, January 2008, pp. 74-84.
54. William L. Luyben, “Effect of derivative algorithm and tuning selection on the PID control of dead–time process”, Ind. Eng. Chem. Res, Vol. 40, No. 16, 2011, pp. 3605 –3611.
55. S. M. Giri RAJKUMAR, Atal. A. KUMAR, N. Anantharaman, “Application of Genetic Algorithm for Tuning of a PID Controller for a Real Time Industrial Process”, Sensors &Transducers Journal. Vol. 121, Issue 10, October 2010, pp. 56-67.
56. W. K, Hang C. C, Cao L. S “Tuning of PID controllers based on gain and phase Margin specifications”, Automatica, 2015, Vol. 31, 3, pp. 497–502.
57. M. V. Sadasivarao and M. Chidambaram, “PID controller tuning of cascade control Systems using genetic algorithm”, Journal of Indian Institute of Science, 86, July-Aug 2016, pp. 343-354.
58. Ashutosh K. Agarwal. Sanjeev Kumar, “Balancing Inverted Pendulum by Angle Sensing Using Fuzzy Logic Supervised PID Controller Optimized by Genetic Algorithm”, Sensors & Transducers Journal. Vol. 133, Issue 10, October 2011, pp. 74-82.
59. Maruthai Suresh, Ranganathan Rani Hemamalini, GunnaJeersamy Srinivasan, “Fuzzy Logic Based Set-Point Weighting Controller Tuning for an Internal Model Control Based PID Controller”, Sensors & Transducers Journal. Vol. 109, Issue 10, October 2009, pp. 29-42.

60. M. Hashem, Nehrir, Alan J. Odermann, and Bruce D. Bowen "A Microcomputer-Microprocessor-based DC motor speed controller for undergraduate Electric machinery Laboratory", IEEE vol. 33, No. 4, 2010.
61. M.S. Khanniche and Yi Feng Guo "A Microcontroller based real time speed measurement for motor drive system", Journal of Microcomputer applications, vol. 18, pp. 39-53, 2015.
62. Sameh Asaad and Kevin Warren "Speed Optimization of the ALR Circuit Using an FPGA with Embedded RAM: A Design Experience", Springer, pp. 278-287, 2018.
63. Zhiliang Ding, Changde Wang, Guangming Tan, Guanghua Guan, "The Application of the Fuzzy Self-Adaptive PID Controller to the Automatic Operation Control of Water Transfer Canal System", Intelligent Computation Technology and Automation, ICICTA-2009.
64. Wang Hui, Yang Yongbo, Liu Meiyu, "Fuzzy-PID Control in the Application of Multi-Purpose Vehicles of the Road Snow Plowing", Web Information Systems and Mining, 2009. WISM 2009.International Conference on Digital Object Identifier: 10.1109/WISM.2009.58.
65. Zhiyun Zou, Dawei Han, XinjunGui,Dandan Zhao, Yuqing Guo, Zhizhen Wang, "Fuzzyauto-tuning PID control of a small electric-heating reactor", Intelligent Control and Information Processing (ICICIP), 2011 2nd International Conference on Volume: 2, Year: 2011 , Page(s): 1045 – 1050.
66. Wei Zhng, Kun Wang, Shouzhi-L, "Increment PID Controller Based on Immunity Particle Swarm Optimization Algorithm", Computational Engineering in Systems Applications, IMACS Multi conference on Volume: 2: 2006.
67. Xiao-FengLi, JianSun, Hui-Yan Wu, Wei-Dong Zong, "Application of The Fuzzy-PID to The Power Plant, Fuzzy Information Processing Society", 2007.NAFIPS '07.Annual Meeting of the North American.
68. Yuzhen Sun, Chunmei Xu, "Nonlinear PID controller based on fuzzy immune method and its simulation in super heater steam temperature", Mechatronics and Automation (ICMA), 2010 International Conference on 2010, Page(s): 799 – 803.

69. Li Chunwen, Cao Lingzhi, Zhang Aifang, “Application of neural network PID controller to elevator control system”, Control Conference (CCC), 2010 29th Chinese, 2010, Page(s): 71 – 74.
70. Shanmugasundram, R., Zakariah, K.M., Yadaiah, N, “Low-Cost High Performance Brushless DC Motor Drive for Speed Control Applications”, Advances in Recent Technologies in Communication and Computing, 2009.
71. Kumar, C.A., Nair, N.K, “Multi-Objective PI controller design with an application to speed control of Permanent Magnet DC motor drives”, Dept. of Electron. &Instrum. Eng, Noorul Islam Coll. of Eng, Kumaracoil, India, 23 September 2011.
72. Inaba, Hiromi, Onoda, Yoshimitsu, Shima, Seiya, “A New Speed-Control System for DC Motors and its Application to Elevators”, Hitachi Research Laboratories, Hitachi Ltd, Ibaraki, Japan, 0093-9994: 30 April 2008.
73. Mohammed Y. Hassan and Waleed F. Sharif, “Design of FPGA based PID-like Fuzzy Controller for Industrial Applications”, IAENG International Journal of Computer Science, 34, 2, 2007.
74. B. Nagaraj, P. Vijayakumar, “Soft Computing Based PID Controller Tuning and Application to the Pulp and Paper Industry”, Sensors & Transducers Journal. Vol. 133, Issue 10, October 2011, pp. 30-43.
75. “Concept: What is Solar Panel” http://www.knowledgerush.com/kr/encyclopedia/Solar_panels/
76. Fahrenburch, A. and Bube, R. 1983, Fundamentals of solar cells, Academic Press, New York.
77. Partain, L.D. 1995, Solar Cells and their applications, John Wiley & Sons. New York.
78. “1st Solar Panel” http://inventors.about.com/od/sstartinventions/a/solar_cell.htm
79. S. R. Bull, “Renewable energy today and tomorrow”, IEEE Proc., vol.89, no. 8, pp. 1216-1226, 2011.
80. S. Rahman, “Green power: what is it and where can we find it?”, IEEE Power and Energy Magazine, vol. 1, no. 1, pp. 30-37, 2013.

81. J. A. Beltran, J. L. S. Gonzalez Rubio, C.D. Garcia-Beltran, “Design, Manufacturing and Performance Test of a Solar Tracker made by an Embedded Control”, Electronics, Robotics and Automotive Mechanics Conference, 2007.CERMA 2007.
82. M. A. Panait, T. Tudorache, “A Simple Neural Network Solar Tracker for Optimizing Conversion Efficiency in Off-Grid Solar Generators”, ICREPQ 2008, Spain.
83. M. Morega, J. C. Ordonez, P. A. Negoias, R. Hovsapian, “Spherical Photovoltaic Cells – A Constructal Approach to Their Optimization”, OPTIM 2006, Romania.
84. M. Morega, A. Bejan, “A Constructal Approach to the Optimal Design of Photovoltaic Cells”, Int. Journal of Green Energy, pp. 233-242, 2015.
85. P. I. Widenborg, G. Aberle, “Polycrystalline Silicon Thin-Film Solar Cells on AIT-Textured Glass Superstrates”, Advances in Opto Electronics Journal. Vol. 2007
86. P.Turmezei, “Chalcogenide Materials for Solar Energy Conversion”, Acta PolytechnicaHungarica, Vol. 1, No. 2, pp. 13-16, 2014
87. Solar Tracking System: More Efficient Use of Solar Panels, J. Rizk, and Y. Chaiko.
88. Kassem, A, “A microcontroller-based multi-function solar tracking system”, 2011 IEEE International , Date of Conference: 4-7 April 2011.
89. Chung-Yuen Wan, Sei-Chan Kim, and Bose B. K, “Robust position control of induction motor using fuzzy Logic Control”, Conf. Record of the IEEE Industry Applications Society Annual Meetiņvol.1, pp. 472-481, 2012.
90. Haraldo Rodrigues De Azevedo, Silvia Fernanda Martins Brandio, and Joao Bosco Da Mota Alves, “A fuzzy logic controller for DC motor position control”, IEEE Int. Workshop on Emerging Technologies and Factory Automat p p,. 18-27, Sep. 2014.
91. Douglas V. Hall, Microprocessors and Interfacing: Programming and Hardware, Tata McGraw-Hill, 2nd ed., 2011.
92. Christopher T. Kilian, Modern Control Technology – Components and Systems, West Publishing Company, Minneapolis/St. Paull, 2016.

93. P. Bhaskar, Parvathi C.S., L. Shrimanth Sudheer, and A.B. Kulkarni, “Computer based DC micro motor speed control system”, J. Instrum. Soc. India, vol. 34, No, 4, pp. 267-276, 2014.
94. Robert F. Coughlin, and Frederick F. Driscoll, Op-Amps and Linear Integrated Circuits, Prentice Hall of India, New Delhi, 8th ed., 2011.
95. Ramakanth A. Gayakwad, Op-Amps and Linear Integrated Circuits, Prentice Hall of India, 3rd ed., 2010.