An Efficient Heading Control of Underwater Vehicle using FPGA based Real Time Controller (cRIO) and LabVIEW

N. Revathi[1], D. Dineshkumar[2], S. Radhika[3], P. Muthuvel[4]
[1]PG Scholar, Dept of ECE, Sri Venkateswara College of Engineering, Sriperumbudur.
[2]Project Scientist-I, National Institute of Ocean Technology, Chennai.
[3]Assistant Professor, Dept of ECE, Sri Venkateswara College of Engineering, Sriperumbudur.
[4]Scientist-E, National Institute of Ocean Technology, Chennai.

Abstract:- **An improvement of efficient control strategy for the underwater vehicles to maneuvre in constrained locations, overcoming the external disturbances, has been a real challenge in study of underwater resources. A high degree of autonomy is particularly desirable in sub-sea exploration. This project aims to develop efficient control logic for an underwater vehicle. A combination of PID control logic for heading control of the underwater vehicle was developed by a graphical coding language, LabVIEW. In order to achieve optimum solutions K_p, K_i and K_d gains are arranged according to the system characteristics. Control logic was implemented in a embedded real-time control and acquisition system, CompactRIO (Reconfigurable input output) along with input output modules in a FPGA chassis. The results of the simulation for various gain tuning steps including delay optimization were satisfied.**

Keywords- PID control logic, heading control, LabVIEW, CompactRIO.

I. INTRODUCTION

The underwater vehicle can perform various underwater tasks, ranging from seafloor surveying, lost asset location, underwater rescue and ocean cable inspection. These appliances impose a very strict positioning and force requirement onto the controller. However, underwater vehicle's dynamics is intrinsically time variant and non-linear i.e., its mass and buoyancy change according to different working conditions. It also subject to uncertain external disturbance and the hydrodynamic forces are hard to model. Coriolis force and Pressure are another significant factor that should be considered in the design process [4] and [6].

To control the motion of an underwater vehicle, the heading control problem is a significant one. The change of the desired heading direction and the change of vehicle's heading under the real environment are the problems. In addition, the speed of a vehicle will drastically affect the motion of the vehicle. A PID controller calculates and results a corrective heading direction. The controller output is obtained by adding a Proportional, Integral, and Derivative components and their associated coefficient [1]. In a proportional controller, the control variable is proportional to the error signal. Most of the operation need offset to work so extra intelligence is added to a proportional controller by producing an integral term to the proportional controller. The function of adding a derivative term is to reduce the correction time. If error undergoes an initial large change, differentiation yields a large value that drives the process. This results in the faster response of the system. The result from the derivative decreases with time and become negligible as the error approaches zero. It is a noisy process whose amplitude is small but the frequency is quite high.

The heading control logic was implemented in a CompactRIO, real-time controller with hot swappable Input Output modules on a reconfigurable FPGA chassis, and graphical LabVIEW software for real time programming.

Figure1. CompactRIO with IO modules**.**

Controllers are compatible with National Instruments C Series IO Modules. CompactRIO is designed to work in a harsh environment and small places [3]. The succeeding sections will discuss about the proposed PID control logic of heading control, hardware configuration and experimental results.

II. PROPOSED WORK

This paper proposes an application that highlights the heading control of the underwater vehicle using PID controller through CompactRIO. The PID controller receives desired heading direction and controls current heading of the vehicle to move in the desired direction in order to accomplish predefined coordinates. A proposed block diagram to the closed loop heading control for an underwater vehicle is shown in figure 2.

The heading value from c100 compass is given as a process input to the PID controller. The c100 compass is a complete stand alone sensor, outputs an accurate heading data in a four digit BCD with an output voltage of 0.9 to 1.9 VDC. The PID controller calculates and results a corrective action that corrects error between the process output and desired heading direction also adjusts the process accordingly and rapidly. For a desired control response control parameters were arranged to optimum value by a tuning method. Tuning of PID controller changes the gain values i.e. K_p, K_i, and K_d to obtain stability of the process.

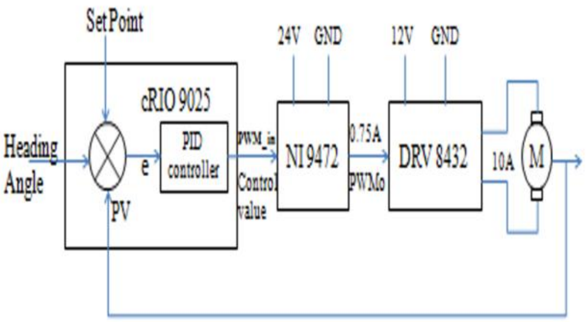

Figure2. Block diagram of proposed logic.

An analog voltages and current can be used to control processes directly but it is not always practical to do because analog circuits tend to drift over time and difficult to tune. The digital Control of an analog circuit will greatly reduce cost as well as power the consumption. The Pulse width modulation is a method of digitally encoding analog signal levels and the duty cycle of a square wave will be modulated to set a specific analog signal level. Using the specialty digital configuration of NI 9472(Sourcing digital output) module, PWM output was chosen and the switching frequency of PWM can be set as shown in figure3.

The current required to drive the thruster is 10A but source current from NI 9472 is low as 0.75A. In order to drive load, an efficient driver circuit is essential. The DRV8432 solve this issue by providing 12A continuous output current with PWM operating frequency of 500 kHz.

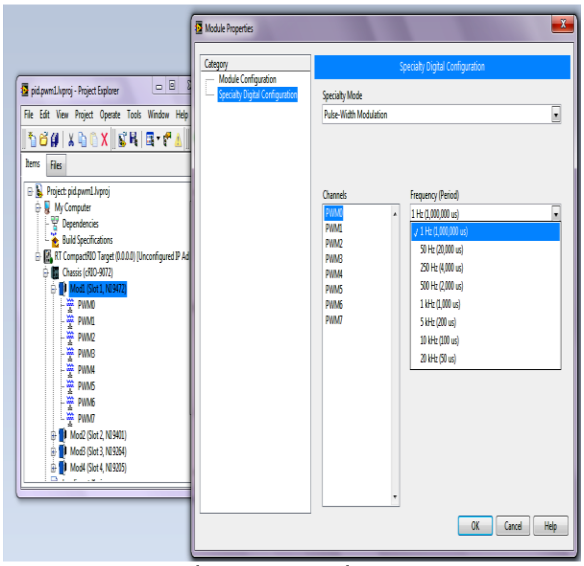

Figure3. Configuring NI 9472 for a PWM output.

III. HARDWARE CONFIGURATION

A. NI cRIO-9025 CONTROLLER

The CompactRIO 9025 allow 9 to 35 VDC power supply inputs while power ON and 6 to 35 VDC power supply inputs during operation, so it can function for long periods of time. Processor speed is 800 MHz and 4GB of non-volatile memory. The controller provides two Ethernet 10/100 ports also Hi-Speed USB host port.

B. NI cRIO-9116 CHASSIS

Eight slot reconfigurable embedded chassis for any compactRIO input output modules. RIO FPGA core can executes at a default rate of 40MHz. The cRIO 9116 chassis uses a Virtex-5 FPGA with enhanced optimization capability it will help to execute code faster.

C. NI 9472 MODULE

Eight channel sourcing digital output module. Maximum output voltage is 30V DC and output current of 0.75mA. The maximum output delay time is 100 micro seconds.

D. DRIVER CIRCUIT DRV 8432

Dual full-Bridge PWM motor driver with continues output current of 12A. PWM Operating Frequency up to 500 kHz. Operating supply voltage: 50 V integrated self-protection circuits including under voltage, over temperature, overload, and the short circuit.

IV. EXPERIMENTAL RESULTS

A developed LabVIEW Virtual Instrument allows real time control of an underwater vehicle; a virtual block diagram was made known in figure 6 and the results of PID controller for various heading values were shown in figure 5.

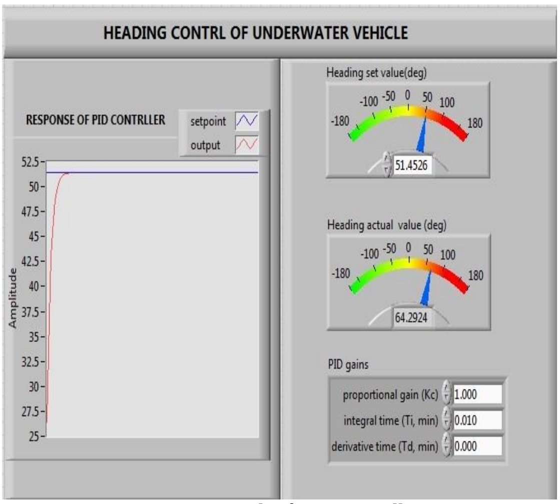

Figure 4. Result of PID controller

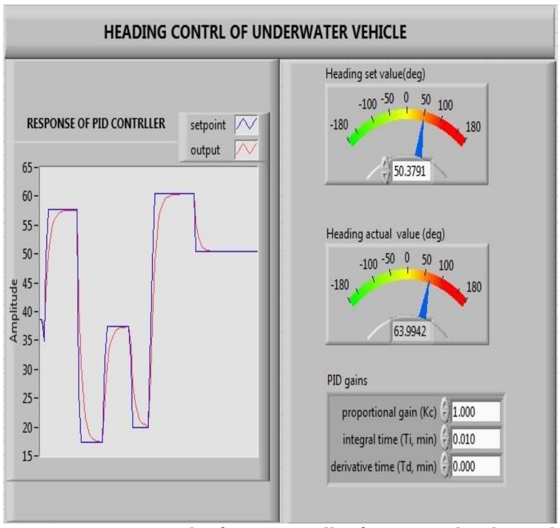

Figure 5. Result of PID controller for various heading values.

The front panel view of Virtual Instrument is presented in figure 4 which allows controller tuning by varying PID gain values to obtain a desired heading set value.

If proportional gain is higher than the finest value; controller operation in the steady state is not stable else the proportional gain is lower than the finest value, the system response is much slower. Overshoot in a process is eliminated by rising integral gain and lowering derivative period.

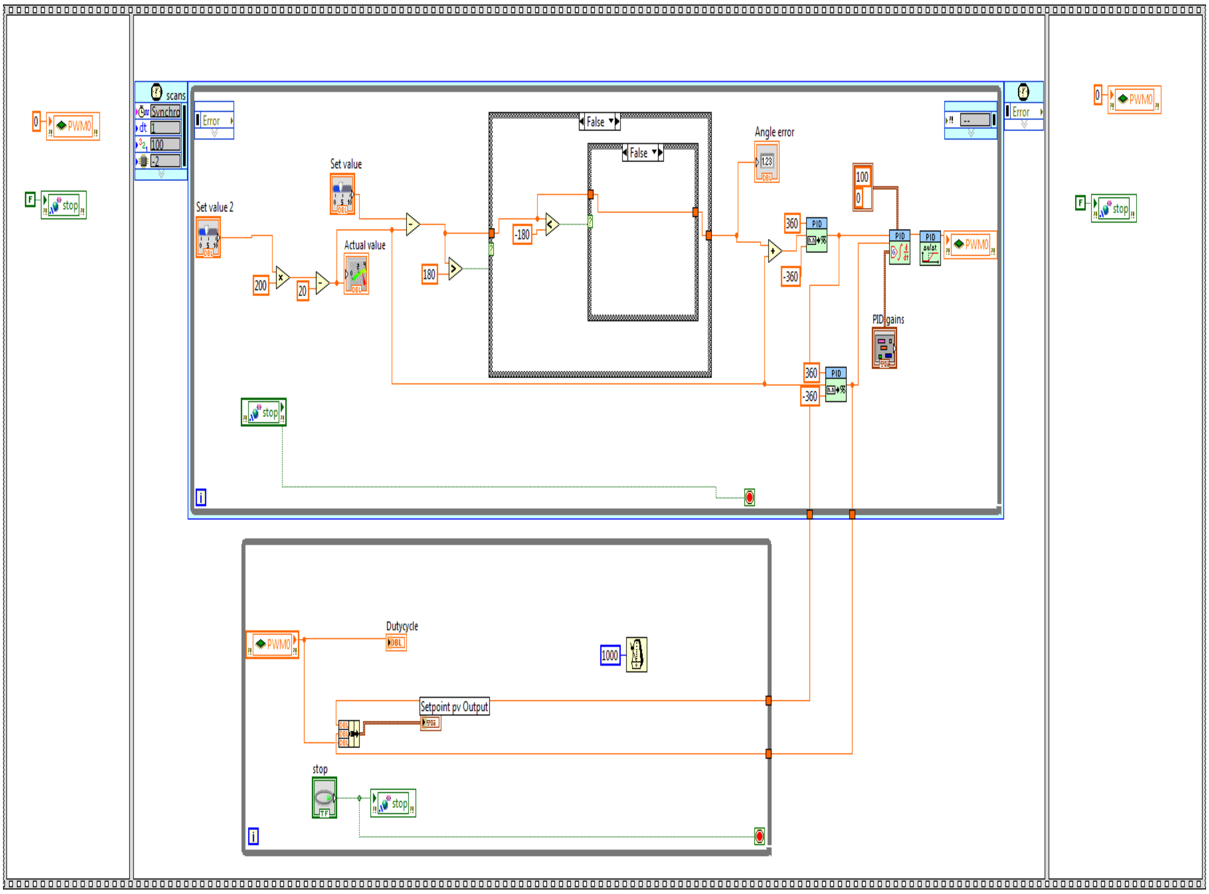

Figure 6. Virtual Instrument block diagram for heading control

For the real time heading control CompactRIO was selected to program in a scan mode of operation. Timed loop provides the ability to synchronize code on various time bases. The loop synchronization, rate of scan engine, and scan period was chosen by configuring time loop on the left side. Loop timing source was synchronized with scan engine it causes the code in timed loop to execute once, immediately after IO scan.

The output from PID controller was given to NI 9472 sourcing digital output module from which PWM signal was generated to control thrusters. The generation of PWM signal was shown in figure7. Thrusters were controlled by a PWM signal by taking physical connection out. Finally the controlled value was feedback to PID controller and the desired response was achieved.

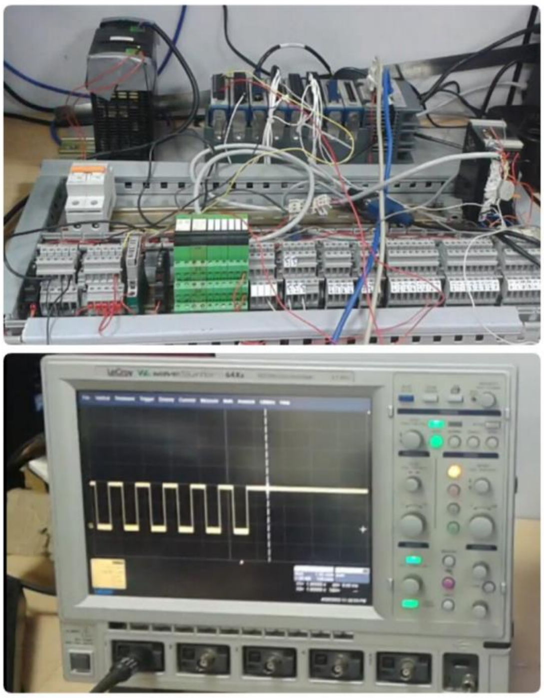

Figure 7. PWM signal generation from NI 9472 DO module for various duty cycles.

V. CONCLUSION

An efficient PID control logic for the heading control of underwater vehicle was developed using CompactRIO, real time controller. From the simulation results delay optimization were satisfied for various heading values by tuning K_P, K_i, and K_d control parameters. The scan mode operations of CompactRIO yield a desired real time heading control. The fastest execution of heading and position control logic in FPGA mode of programming will be implemented in future.

REFERENCES

[1] M. Rata, G. Rata and V. Chatziathanasiou, ‘Solution for the Study and Understanding of PID Controllers,’ International Conference and Exposition on Electrical and Power Engineering, Iasi, Romania DOI:10.1109/ICEPE.2014.6969893, pp. 182 – 185,2014.

[2] M. Horinek and P. Bilik, ‘Power Analyzer for Converter Testing Based on Crio Hardware Platform’, Applied Electronics International Conference, pp. 1-4, 2014.

[3] KimChon Chan,and ChingSeong Tan, ‘Feasibility Study of FPGA based Real-Time Controller for Autonomous Vehicle Applications’, Proceedings of IEEE Conference on Sustainable Utilization, 978-1-4244-7503-21 10/$26.00, 2010.

[4] R. Madhan and P. Maurya,’Potential of autonomous underwater vehicles as new generation ocean data platforms’. Current Science, VOL. 90, NO. 9, 10 MAY 2006.

[5] Øistein Hasvold and Nils J.Størkersen, ‘Power sources for autonomous underwater vehicles’, Journal of Power Sources 162- 935–942, 2006.

[6] Azadeh Kebriaee and Hamidreza Nasiri. ‘The AUV design based on component modelling and simulation’, Ocean Systems Engineering, Vol. 2, No. 2 - 83-97, 2012.

[7] Muhammad Tahir Zia, Andrew Curley, Olga Duran and Omid Razmkhah,’ Application of LabView and cRIO for high precision positioning of Mars rover using DC motors’, Kingston University London.

[8] CompactRIO: A new class of embedded http://smallformfactors.opensystemsmedia.com/articles/compactrio-new-class-embedded/

[9] ***,CompactRIO,http://www.ni.com/compactrio/.