Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı, S. 262-267, Eylül 2020

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue, pp. 262-267, September 2020

Research Article

Design of Communication and Power Systems in Unmanned Underwater Vehicles

Ercan Ataner[1]*, Büşra Özdeş[2], Gamze Öztürk[3], Taha Yasin Can Çelik[4], Akif Durdu[5], Hakan Terzioğlu[6]

[1]Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0002-4548-9968)
[2]Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0002-3902-3053)
[3]Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0003-3278-0016)
[4]Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0002-3955-0953)
[5]Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0002-5611-2322)
[6]Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0001-5928-8457)

(1st International Conference on Computer, Electrical and Electronic Sciences ICCEES 2020 – 8-10 October 2020)

(**DOI:** 10.31590/ejosat.803213)

ATIF/REFERENCE: Ataner, E., Özdeş, B., Öztürk, G., Çelik, T. Y. C., Durdu, A. & Terzioğlu, H. (2020). Design of Communication and Power Systems in Unmanned Underwater Vehicles. *European Journal of Science and Technology*, (Special Issue), 262-267.

Abstract

Unmanned underwater vehicles (ROV/AUV) are robotic systems that can float underwater, are autonomous and remotely controlled. The first unmanned underwater vehicle on record was designed by Luppis Whitehead Automobile in the form of a torpedo in 1864. The first vehicle designed in the same sense used today was designed by Dimitri Rebikoff in 1953. Today, unmanned underwater vehicles are used in a wide range of areas such as underwater search and rescue operations, ship underwater maintenance and repair operations, taking images from dangerous environments where divers cannot enter, military use, inspection of wrecks and underwater cleaning.

The design stages of underwater vehicle control system are given in this study. The system consists of control cards, communication modules, sensors, lighting and power electronics elements. The basic philosophies followed for the design of the system are modularity and safety. This situation provides ease in the organization of the components in the underwater vehicle as well as the modular structure, the test and repair stages are easily carried out. To ensure modularity, the system is divided into two subcomponents as power and control units. In addition, a computer interface is used to control the underwater vehicle. With this interface, data is exchanged with underwater vehicles so that the depth, water temperature and temperature of the sealed tube containing the electronic components can be monitored. Another task of the computer interface is to transfer the camera image taken from underwater to the user.

In this study, the remote control of unmanned underwater vehicles, the power system, communication infrastructure, the design of the structure that provides the transmission of the image and sensor information taken from underwater is mentioned.

Keywords: Control, Modular Design, ROV (Remotely operated underwater vehicle), System Design, Software.

İnsansız Su Altı Araçlarında Haberleşme ve Güç Sistemlerinin Tasarımı

Öz

İnsansız su altı araçları (ROV/AUV) su altında yüzebilen, otonom ve uzaktan kontrol edilebilen robotik sistemlerdir. Kayıtlardaki ilk insansız sualtı aracı Luppis Whitehead Automobile tarafından 1864 yılında torpido şeklinde tasarlanmıştır. Günümüzde kullanılan manasıyla tasarlanan ilk araç ise 1953 senesinde Dimitri Rebikoff tarafından tasarlanmıştır. Günümüzde insansız su altı araçları su altı arama kurtarma çalışmaları, gemi su altı bakım ve onarım işlemleri, dalgıçların giremeyeceği tehlikeli ortamlardan görüntü alma, askeri amaçlı kullanım, batıkların incelenmesi ve su altı temizliği gibi çok geniş bir alanda kullanılmaktadır.

Çalışmada su altı aracı kontrol sisteminin tasarım aşamaları verilmiştir. Sistem kontrol kartları, iletişim modülleri, sensörler, aydınlatma ve güç elektroniği elemanlarından oluşmaktadır. Sistemin tasarımı için takip edilen temel felsefeler modülerlik ve güvenliktir. Bu durum bileşenlerin su altı aracı içerisindeki organizasyonunda kolaylık sağladığı gibi modüler yapı sayesinde test ve onarım aşamaları kolaylıkla gerçekleştirilir. Modülerliği sağlamak amacıyla sistem güç ve kontrol birimi olarak iki alt bileşene ayrılmıştır. Ayrıca su altı aracının kontrolü için bir bilgisayar arayüzü kullanılmaktadır. Bu arayüz sayesinde su altı aracı ile veri alışverişi yapılmakta bu sayede derinlik, su sıcaklığı ve elektronik bileşenleri içerisinde bulunduran sızdırmaz tüpün sıcaklığı takip

* Corresponding Author: Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye, ORCID: 0000-0002-4548-9968, ercanataner@gmail.com

edilebilmektedir. Bilgisayar ara yüzünün bir diğer görevi ise su altından alınan kamera görüntüsünün kullanıcıya aktarılmasını sağlamaktır.
Bu çalışmada insansız su altı araçlarının uzaktan kontrolü, güç sistemi, iletişim alt yapısı, su altından alınan görüntünün ve sensör bilgilerinin kullanıcıya aktarımını sağlayan yapının tasarımdan bahsedilmektedir.

Anahtar Kelimeler: Kontrol, Modüler Tasarım, ROV (Remotely operated underwater vehicle), Sistem Tasarımı, Yazılım.

1. Introduction

Studies on unmanned underwater vehicles (ROV-AUV) have shown a rapid increase, especially in recent years. Remote control (ROV) and autonomous underwater vehicles (AUV) (Schjølberg & Utne, 2015) have begun to be used field of oceanographic research, bathymetric measurements, underwater maintenance activities and military defense, equipped with a wide range of sensors and auxiliary equipment in addition to their existing equipment (Yildiz, Yilmaz, & Gokalp, 2009).

ROV can also be called a remotely operated vehicle underwater or a mobile robot designed for underwater work environments. The remote control of the vehicle is carried out via a power and communication cord through a user interface. The main drawback in ROV use is that visual inference and evaluations have become more difficult due to the loss of human presence. However, in addition to advanced imaging systems, autonomous vehicles with high mobility are being designed to overcome this problem (Ahmed, Yaakob, & Sun, 2014).

The first ROV developers are still unknown, but pioneers in the ROV development process are considered to be an underwater vehicle developed by Dimitri Rebikoff in 1954, called a torpedo and POODLE developed by Luppis - Whitehead Automobile in 1864. The use of ROVs to operational size was carried by the U.S. Navy. U.S. Navy begins development of some kind of underwater robot to recover underwater weapons lost during naval tests. The U.S. Navy has pioneered the operational use of underwater vehicles with the Rescue of an atomic bomb lost off the Spanish town of Palomares in a plane crash in 1966 and Rescue of crew of submarine that sank off Ireland (Moore, Bohm, Jensen, & Johnston, 2010).

In our country, the ROVs, which began to be used on experimental U.S. mine exploration ships in the 1970s, were first procured from abroad in the 1990s and started to be used as a limited number of MK series in the Navy's mine exploration fleet. In 1996, the Navy command, seeking domestic product supply due to restrictions on its supply, first examined the SUTA (Research Institute for underwater technologies) ROV, but later decided to work with TUBITAK on this issue. ULISAR project under TUBITAK organization can be given as the first serious study in this field in our country. The Multi-Purpose National Unmanned Underwater Vehicle ULISAR, developed by Middle East Technical University with the support of TUBITAK, is a lightweight ROV that is intended to dive up to 100 M and is controlled via acoustic link. July 1, 2006 - July 1, 2009, the project was carried out on an academic basis and is the first important step in Turkey in this regard on the basis of conceptual proof. At the end of the project, the desired goals were not fully achieved. however, capable of visual navigation on them, cameras, searchlights, sonar, sonar, modem and other similar devices where acoustic sensors are installed, the relevant electronic cards are designed and prepared, where preparation of the software on these devices so as to provide convenience to the user resides on an operator console system was created (Canlı, Kurtoğlu, Canlı, & Tuna).

Recently, demand for low-cost ROV by private companies, Professional Studies, University students and public organizations has increased. This work includes an effective hardware-software combination that allows monitoring data collection or control of underwater vehicles for military uses.

2. Material and Method

The main philosophies followed for system design are modularity and security. This makes it easy to organize the components in the vehicle, and the testing and repair stages are easily carried out thanks to the modular structure. The underwater vehicle control structure consists mainly of two sub-components, the power system and the communication system.

2.1. Underwater Vehicle Power Systems

In underwater vehicles, the thruster motors used in the vehicle must be strong in order for the vehicle to have a high mobility. This leads to a high need for power in underwater vehicles. Power sources commonly used in unmanned underwater vehicles are batteries and wired supply systems.

Lithium ion batteries are a good alternative to underwater vehicles because they have a high energy density and long cycle life, and have been widely used in mobile phones and laptops for many years (Bradley, Feezor, Singh, & Sorrell, 2001).

The power required by the vehicle can also be transferred to the underwater vehicle using another method, cable, since the vehicle's battery life is a disadvantage due to the limited battery life in long-running operations. with the cable method, underwater vehicles can perform their duties without time constraints. When this type of configuration is used, losses occur in the cables used to provide power. In order to overcome this situation, the transmitted voltage level is kept high and the losses on the cable are minimized.

In the system subject to this study, the vehicle is designed as wired. Since the electronic components are working under water, the voltage level has been tried to be kept at a safe level by considering possible insulation problems. So the voltage is selected as 48V and the system is designed accordingly. The designed vehicle needs 48V/25A power at full performance. Since the components used in the vehicle require 12V and 5V voltages, the required voltage levels have been adjusted to the desired level by using appropriate DC-DC converters within the vehicle. The voltage conversion takes place in two stages. In the first stage the voltage is reduced from 48V DC to 12V DC. At this stage, two DC-DC converters were used and the load on them was shared equally to prevent overloading of DC-DC converters. In this way, a reliable structure has been obtained. In the second stage the voltage is reduced from 12V DC to 5V DC. Two DC-DC converter used at this stage was used to provide the 5V DC voltage needed by electronic components. In addition, the designed system has Engine Driver (ESC) modules for driving the engines and led driver modules for controlling the lighting system. the design of the power system has been terminated by mount an emergency stop button to cut the power of the system in case of any danger and a fuse to prevent damage to the system in case of possible short out. The block diagram for the designed system is shown in Figure 1.

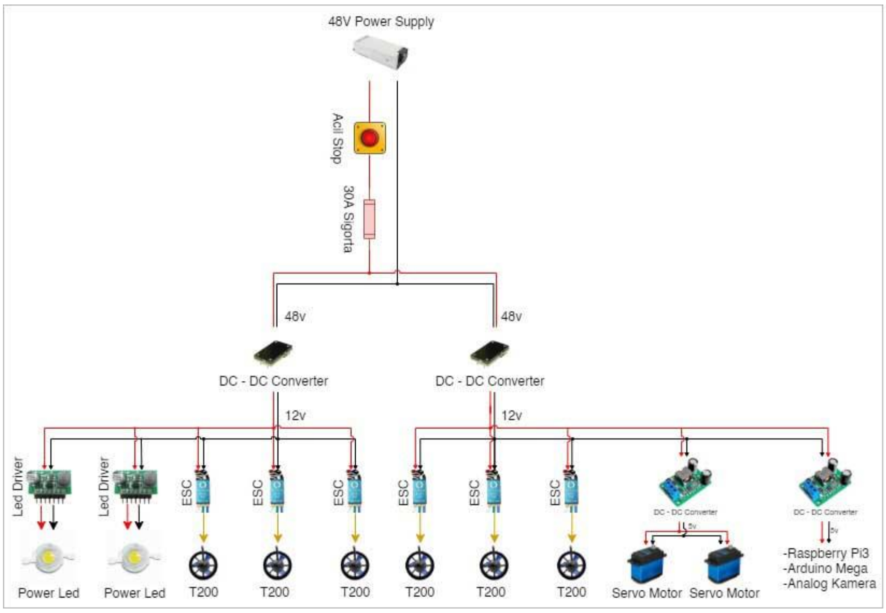

Figure 1. Power distribution schema block diagram

2.2. Water Vehicles Communication Systems

The fact that seawater behaves in very limited bands and permeable to a certain extent within the electromagnetic spectrum makes it very difficult to use wireless communication in underwater communication. In addition, acoustic communication systems have been developed for wireless communication under water (Freitag & Catipovic, 1989; KAHVECİ, 2013; Llor & Malumbres, 2010).

In this study, wired communication system from communication systems was discussed and the necessary designs were made in this direction. The system consists of sensors, camera, control board and communication module.

Underwater vehicles can be equipped with a wide range of sensors in accordance with the tasks they will be used. Sonar, magnetometer, barometer, conductivity and temperature sensors are examples of these. Within a decade, developed commercially available, precise, high update rate navigation sensors such as Doppler sonars, optical gyroscopes and inertial measurement units (IMU) (Ahmad, Ghazilla, Khairi, & Kasi, 2013; Höflinger, Müller, Zhang, Reindl, & Burgard, 2013). so,it has outperformed traditional underwater sensors such as acoustic positioning systems and magnetic compasses (Kinsey, Eustice, & Whitcomb, 2006). The sensors used in the designed system are Temperature Sensor, Pressure sensor and IMU. The temperature sensor has been used to measure ambient temperature. The pressure sensor was used to obtain the depth information of the vehicle, while the IMU was used to provide a feedback signal to the PID control system, which was used to control the balance of the vehicle.

Since wireless communication is not possible under water, communication is carried out on a wired basis. For long-distance wired communication, communication modules suitable for the system should be used to deliver data to the control element without loss. The Fathom-s tether interface card was used to provide communication between the control unit and the computer interface. This card provides the necessary communication and video signals for the underwater vehicle through a single communication line. The received data is transferred to the computer via USB-TTL conversion at the above-water control station and can be monitored via the interface.

Since the Fathom-s card used in the system supports an analog camera, an analog camera selection has been made to be suitable for use with this card. A camera with high performance in low light is selected so that the user can control the vehicle in low light conditions.

The tasks of the control unit, consisting of a microcontroller card, are to read the data from the sensors on the vehicle, provide control of the vehicle, and transfer the resulting sensor data to the user. Arduino Mega 2560 microcontroller board was used in the designed system. The most basic task of this card is to balance the vehicle with the PID control system by using the data it receives from IMU. The PID control method is a feedback control mechanism commonly used in industrial control systems (Johnson & Moradi, 2005; Maalouf et al., 2013; Shen, Cao, Zhou, Xu, & Gu, 2013). A PID controller calculates an "error" value by taking the difference between the measured value and the desired reference value. The PID Controller aims to achieve the measured value to the desired reference value by controlling the process input (Ang, Chong, & Li, 2005; Knospe, 2006). The error value used in balance control consists of the difference between the angle values read from the IMU and the reference value. The PID control system aims to bring this error value to the reference value by driving the engines associated with PID algorithms. The underwater engines used in the system are driven by PWM method. The PID control algorithm is shown in Figure 2.

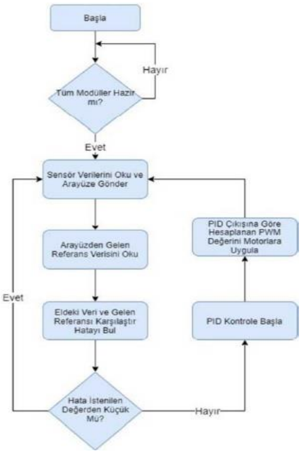

Figure 2. PID control algorithm

Communication with the above-water control station is provided by the UART protocol. UART is one of the simplest and most widely used serial communication techniques. Almost all microcontrollers have UART hardware built into their architectures. Today, UART, GPS receivers, bluetooth modules, GSM and GPRS modems, wireless communication systems, etc. It is used in many areas such as (Chun-Zhi, Yin-shui, & Lun-yao, 2011; Norhuzaimin & Maimun, 2005). In Figure 3, the block diagram for the communication system is given.

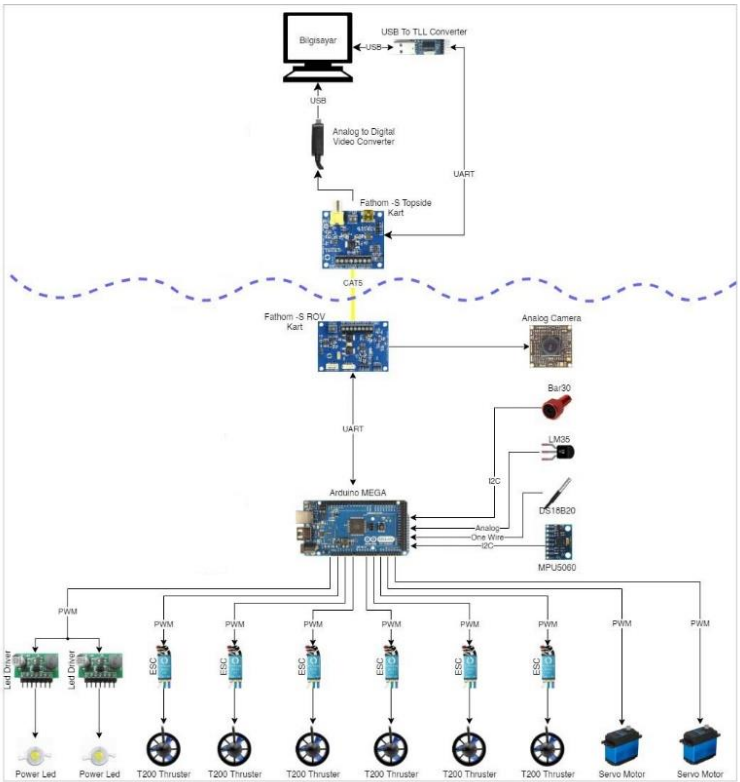

Figure 3. Communication infrastructure of the vehicle

The last part of the system is computer software. Thanks to the designed computer interface, the vehicle can be controlled with any commercially available joystick. The computer interface, in which the image taken from the vehicle camera is transmitted to the user, and the sensor data contained on the vehicle can be monitored instantly, has been prepared in Visual Studio in C#. The interface provides communication with the underwater vehicle via the UART Protocol (Pardue, 2007). Computer interface is shown in Figure 4.

Figure 4. Computer interface

3. Results and Discussion

The power needs of the designed underwater vehicle were supply wired and a design was made in this direction. Since 1200W, the maximum power required by the vehicle, will be transferred to the vehicle with a voltage of 48V, the cable section required at a distance of 25m for a maximum voltage drop of 3% is calculated as follows;

For $P = 1200W$;

$$S = \frac{100 * P * L}{k * \%e * U^2} = \frac{100 * 1200 * 25}{56 * 3 * 48^2} = 7.75 \text{ mm}^2$$

According to the calculation, the minimum cable cross-section that should be used for a voltage drop of 3% was calculated as 7.75 mm^2 according to this calculation, the vehicle has the ability to operate in an area of 25 m radius. The image of the vehicle's pool tests is shown in Figure 5.

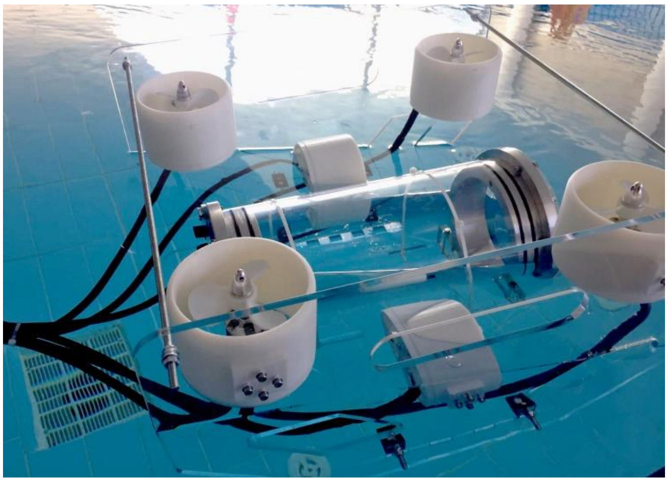

Figure 5. Image of the designed vehicle's pool tests

In addition, the cable in which the vehicle's image and communication signals are carried is the CAT-6 communication cable. The Fathom-S communication module used on the vehicle provides lossless data communication wired from a distance of 100 m.

The power needed to feed the vehicle in unmanned underwater vehicles can be supplied in two ways as a battery and wired feed. Both systems have advantages and disadvantages in themselves. This causes the weight of the vehicle to increase when internal batteries are used to feed the vehicle. İn vehicles using a battery, a high power requirement of the vehicle causes the battery to be consumed quickly. As a result, vehicles cannot be used in long-running operations. However, the battery usage will ease the vehicle's cable load, making the vehicle more flexible and agile. If the power requirement of the vehicle is transported by cable, the vehicle can be used in long-term operations without time limitation since the power is supplied from outside. However, the need for high currents when the vehicle is working causes a voltage drop in the cables.

Since increasing the cable section to prevent voltage drop will restrict the vehicle's mobility, these two options must be examined and the appropriate selection must be made in accordance with the tasks in which the vehicle will be used.

4. Conclusions and Recommendations

Recently, demand for low-cost ROV by private companies, professional studies, university students and public organizations has increased. In this study, which was prepared to meet this demand, stages of implementing electronic and remote control components of unmanned underwater vehicles were given. Designed with modularity, this system is revealed by enabling the units undertaking different tasks and functions to operate as a whole. The design of the control structures of unmanned underwater vehicles is difficult, but due to the increase in the use of unmanned underwater vehicles in recent years, it is one of the current issues. The designed control system is unique to the vehicle and can be mass-produced. In this way, it can easily become a tool that can be worked and improved. In addition, additional equipment can be added to the vehicle, providing autonomous capabilities, and can be used in national and international unmanned underwater competitions.

References

Ahmad, N., Ghazilla, R. A. R., Khairi, N. M., & Kasi, V. (2013). Reviews on various inertial measurement unit (IMU) sensor applications. *International Journal of Signal Processing Systems, 1*(2), 256-262.

Ahmed, Y. M., Yaakob, O., & Sun, B. K. (2014). Design of a new low cost ROV vehicle. *Jurnal Teknologi, 69*(7).

Ang, K. H., Chong, G., & Li, Y. (2005). PID control system analysis, design, and technology. *IEEE transactions on control systems technology, 13*(4), 559-576.

Bradley, A. M., Feezor, M. D., Singh, H., & Sorrell, F. Y. (2001). Power systems for autonomous underwater vehicles. *IEEE Journal of oceanic Engineering, 26*(4), 526-538.

CANLI, G. A., KURTOĞLU, İ., CANLI, M. O., & TUNA, Ö. S. DÜNYADA VE ÜLKEMİZDE İNSANSIZ SUALTI ARAÇLARI İSAA-AUV & ROV TASARIM VE UYGULAMALARI. *GİDB Dergi*(04), 43-75.

Chun-Zhi, H., Yin-shui, X., & Lun-yao, W. (2011). *A universal asynchronous receiver transmitter design.* Paper presented at the 2011 International Conference on Electronics, Communications and Control (ICECC).

Freitag, L. E., & Catipovic, J. (1989). *A signal processing system for underwater acoustic ROV communication.* Paper presented at the Proceedings of the 6th International Symposium on Unmanned Untethered Submersible Technology.

Höflinger, F., Müller, J., Zhang, R., Reindl, L. M., & Burgard, W. (2013). A wireless micro inertial measurement unit (IMU). *IEEE Transactions on instrumentation and measurement, 62*(9), 2583-2595.

Johnson, M. A., & Moradi, M. H. (2005). *PID control*: Springer.

KAHVECİ, S. (2013). Sualti akustik haberleşme. *Karadeniz Teknik Üniversitesi, Mühendislik Fakültesi*, 1-97.

Kinsey, J. C., Eustice, R. M., & Whitcomb, L. L. (2006). *A survey of underwater vehicle navigation: Recent advances and new challenges.* Paper presented at the IFAC Conference of Manoeuvering and Control of Marine Craft.

Knospe, C. (2006). PID control. *IEEE Control Systems Magazine, 26*(1), 30-31.

Llor, J., & Malumbres, M. P. (2010). Modelling underwater wireless sensor networks. *Wireless Sensor Networks: Application-Centric Design, Ed. InTech Education and Publishing*, 185-203.

Maalouf, D., Tamanaja, I., Campos, E., Chemori, A., Creuze, V., Torres, J., & Lozano, R. (2013). From pd to nonlinear adaptive depth-control of a tethered autonomous underwater vehicle. *IFAC Proceedings Volumes, 46*(2), 743-748.

Moore, S., Bohm, H., Jensen, V., & Johnston, N. (2010). Underwater Robotics. *Science, Design and Fabrication. Marine Advanced Technology Education Center (MATE), Monterrey CA, USA*.

Norhuzaimin, J., & Maimun, H. (2005). *The design of high speed UART.* Paper presented at the 2005 Asia-Pacific Conference on Applied Electromagnetics.

Pardue, J. (2007). *Virtual Serial Port Cookbook*: Smiley Micros.

Schjølberg, I., & Utne, I. B. (2015). Towards autonomy in ROV operations. *IFAC-PapersOnLine, 48*(2), 183-188.

Shen, F., Cao, Z., Zhou, C., Xu, D., & Gu, N. (2013). Depth control for robotic dolphin based on fuzzy PID control.

Yildiz, O., Yilmaz, A. E., & Gokalp, B. (2009). State-of-the-art system solutions for unmanned underwater vehicles. *Sensors, 1,* 2.