

# Circuit design solutions for underwater detection robots

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**Abstract.** In recent years, the exploration and utilisation of the environment has become in full swing with the advancement of technology. However, the environment has also suffered a certain degree of damage in the process. As a result of the increasingly serious environmental problems, various environmental issues have become hot spots in society. Among them, marine environmental problems have undoubtedly become one of the focuses of attention. Therefore, the robot design for underwater water quality detection has become an important issue. This paper will mainly focus on the design and research of the hardware circuit system of the underwater detection robot, and give the relevant design scheme. The underwater robot will achieve the following functions: floating suspension at a certain depth in the ocean; synchronously detecting the radiation intensity of x-rays and  $\gamma$ -rays underwater and transmitting the data to the ground to achieve real-time monitoring; maintaining the dynamic balance in the water. Therefore, this paper analyses the pressure sensor circuit, the inertial sensor circuit, the underwater x-ray and  $\gamma$ -ray detection probe circuit and the DC motor drive circuit, determines the interface relationship of each part, and at the same time, uses the Arduino mega 2560 as the control panel, and provide the appropriate voltage according to the needs of each circuit to achieve the hardware circuit design of the robot.

**Keywords:** Sensor, underwater robot, circuit

## 1. Introduction

The ocean is rich in biological, mineral and marine energy [1]. With the increasing progress and development of society, human exploration of lakes and oceans has gradually deepened [2]. The Earth's oceans account for about 71% of the Earth's surface, containing very valuable resources, and there is great potential for economic development and scientific exploration [3]. Therefore, mankind's exploration of the mysteries of the ocean has never stopped [4]. In recent years, environmental issues have gradually become a focus of attention as the Earth's environment is being damaged by factors such as greenhouse gases and acid rain. Due to the growing need for resources, mankind has increased its exploration and testing of marine resources. However, in addition to the complex underwater environmental problems, there is another problem that is holding mankind back, and that is the problem of underwater pollution. Because of human exploitation and the increasingly bad ecological environment, underwater pollution is also getting more serious, and there will be adverse consequences for humans if they work underwater. Thus there is a great demand for underwater inspection robots. Underwater robots have the advantages of high flexibility, strong operability, safety and reliability, and are widely used in marine resource exploration, ecosystem monitoring, rescue and search [5]. At present,

underwater robots have played an important role in marine fishing, marine resource exploration and development, underwater search and rescue, marine biological sampling and other fields [6].

With the continuous development of human's science and technology, underwater robots have gained huge development. For a long time, as the main tool for human exploration of the underwater world, deep-sea exploration robots have grown by leaps and bounds. Deep-sea robots continue to improve in the depth of exploration and the degree of intelligence. The small exploration class robots suitable for shallow waters is another trend in the development of underwater robots. As for the current stage of the development of ultra-small exploration underwater robots, the market appears more OpenROV project initiated by NASA engineers. OpenROV is an open-source cable underwater robot for underwater exploration and education, whose components are assembled by the buyer. OpenROV uses Beaglebone Black with the OpenROV mirror as the underwater robot controller. Through using the cable and the surface system to establish communication, the controller is responsible for parsing the control commands to make control decisions. OpenROV's maximum dive depth is up to 100m. With the real-time high-definition image transmission, it can flexibly control the underwater exploration missions [7]. Nowadays, the diving depth of underwater robots has been from dozens of metres, hundreds of metres to thousands of metres, and the robot's detection accuracy also becomes higher, which is able to complete a series of complex underwater operations. At present, the United States Woods Hole Oceanographic Institution has developed the "Poseidon" underwater robot, whose maximum dive depth has reached 11,000 metres. The maximum dive depth of the manned submersible "Striver" developed by China Ship Scientific Research Centre has reached 10909m [8].

Underwater robot is a comprehensive system that requires strong interdisciplinary and advanced technology [9], and it is also a kind of underwater submersible with intelligent function, which can move on the surface and underwater. It has vision and other perception systems, and it uses manipulators or other tools through remote control or autonomous operations, replacing or assisting human beings to complete certain surface and underwater operations. According to its degree of intelligence and the use of demand, underwater robots are divided into four categories: towed underwater robots TUV (Towing Underwater Vehicle), remotely operated underwater robots ROV (Remotely Operated Vehicle), unmanned underwater robots UUV (Unmanned Underwater Vehicle), and intelligent underwater robots UUV (Underwater Vehicle). Underwater Vehicle), Remotely Operated Vehicle (ROV), Unmanned Underwater Vehicle (UUV) and Autonomous Underwater Vehicle (AUV). The first two types of underwater vehicles are cabled and manually controlled from the mother ship; the latter two are unmanned, cable-free and autonomous. And they are controlled by pre-programmed and intelligent controls respectively [10].

Therefore, this paper will study the hardware circuit design of autonomous and controllable underwater robots. They can realise the functions of autonomous positioning underwater, maintaining the balance of underwater attitude, detecting the pollution, and transmitting the detected data to the ground, in which the supply of power and the transmission of signals will be realised by cables. Among them, this paper mainly includes the following parts: 1) Overall introduction of control system; 2) Selection of control board and related parameters; 3) Sensor and probe selection and related parameters, and the reasons for their selection; 4) The display of the physical circuit diagram; 5) Control signal communication design

## **2. Underwater control system design**

The underwater motion control system with Arduino as the core communicates with the ground motion control system using RS485 serial port. The underwater motion control system automatically adjusts the state of the underwater robot according to the information collected by the sensors on the Arduino, keeps the underwater robot running stably underwater and performs the tasks as required.

### *2.1. Control board design*

The underwater control system adopts Arduino as the main control board, which has 54 digital I/O ports, of which digital pins 0~13 can provide PWM output, 16 analog I/O ports, 4 pairs of serial data

communication ports, and supports the USB interface and DC power supply. The Arduino drives the thruster by outputting PWM and using the electronic speed controller as the driver. The 6-axis attitude sensor LSM6DSM communicates with the Arduino through the IIC serial port. The bathymetric sensor has a measurement resolution of 2mm and provides a high-precision 24-bit pressure digital output, which communicates with the Arduino through the IIC. Schematic of the Arduino R3 board is shown in the Figure 1.



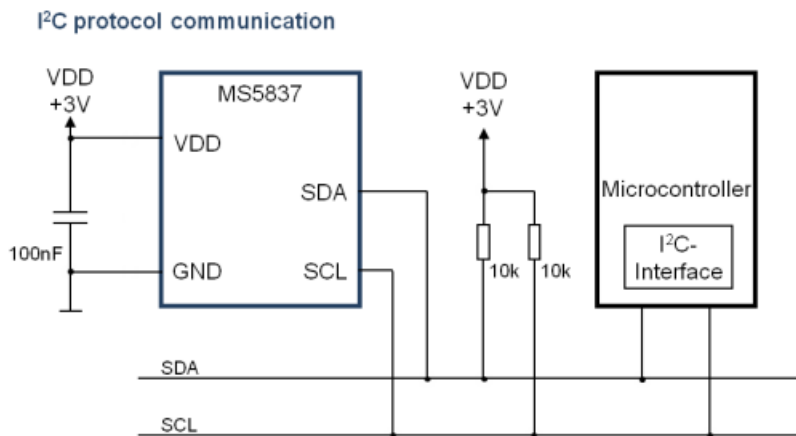
**Figure 1.** Schematic of the arduino R3 board [11]

### 2.2. Pressure sensor design (MS5837)

Parameter index: 1) Supply voltage: 1.5 to 3.6V, 2) I2C interface, address: 1110110x (Write: x = 0, Read: 1=x), 3) Water depth resolution: 2mm, 3) Range: 0-30Bar (0-3Mpa)

Since the robot is required to be able to complete its work underwater at a depth of 300-500 metres, and the MS5837 meets the requirements, the MS5837 is selected as the underwater pressure sensor after integrating the cost and other aspects.

The following Figure 2 shows the typical application circuit of MS5837, using the IIC protocol



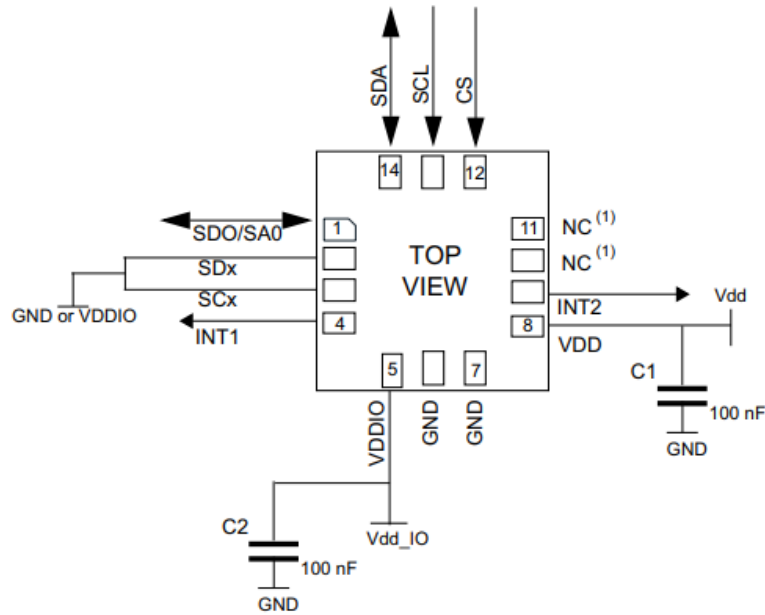
**Figure 2.** The typical application circuit of MS5837 [12]

### 2.3. Inertial sensor design (LSM6DSM)

Parameter index: 1) Voltage: 1.71V-3.6V, 2) Full-scale acceleration range:  $\pm 2/\pm 4/\pm 8/\pm 16$  g, 3) Angular velocity range:  $\pm 125/\pm 245/\pm 500/\pm 1000/\pm 2000$  dps, 4) Operating temperature:  $-40^{\circ}\text{C}$  to  $+85$ , 5) Six-axis corresponds to 3D digital accelerometer and 3D digital gyroscope, 6) Adopting IIC serial port standard output.

Considering the voltage that can be provided by the Arduino motherboard and the temperature and other requirements when working underwater, the LSM6DSM is chosen here as the inertial sensor to enable the underwater robot to complete the adjustment of the underwater attitude and maintain the balance underwater.

The following Figure 3 is the schematic diagram of LSM6DSM connection:

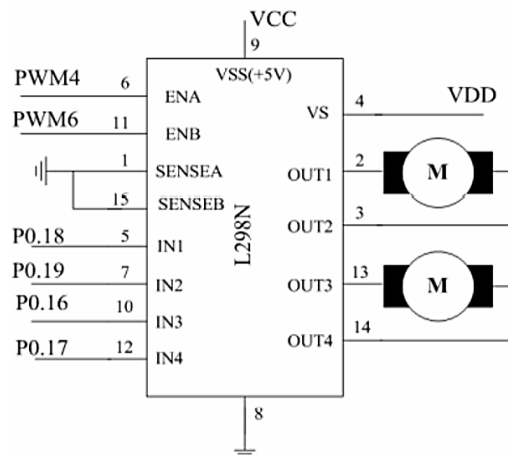


**Figure 3.** The schematic diagram of LSM6DSM connection [13]

#### 2.4. DC motor drive circuit design (motor for 28GM2838, driver chip for L298N)

2.4.1. 28GM2838. Parameter indicators: 1) Rated power: 12W, 2) Rated voltage: 12-24V, 3) Rated current: 0.35-0.55A, 4) Rated speed: 13-1600rpm, 5) Rated torque: 5NM.

2.4.2. L298N. The following Figure 4 is the wiring schematic diagram of L298N.



**Figure 4.** The wiring schematic diagram of L298N [14]

It can be seen that the chip can drive two motors.

#### 2.5. Underwater detection probe design (RW10)

Parameter index: 1) Measuring range: 0.01 $\mu$ Sv/h-1500 $\mu$ Sv/h, 2) Sensitivity: 1 $\mu$ Sv/h $\geq$ 400cps(137Cs), 3) Underwater working depth: up to 1000m, 4) Output port: RS485, 5) Working temperature: -20 $^{\circ}$ C to +50 $^{\circ}$ C, 6) Power supply: 4.5-36VDC.

Considering that the underwater robot mainly completes the detection of underwater x-rays and  $\gamma$ -rays radiation intensity, the underwater x-rays and  $\gamma$ -rays detection probe RW10 is chosen as the detection probe here.

The following picture shows the design of the RW10 probe: the probe can be directly connected to the power supply. The physical image of the RW10 probe is shown in the Figure 5.



**Figure 5.** Physical drawing of RW10 probe [15]

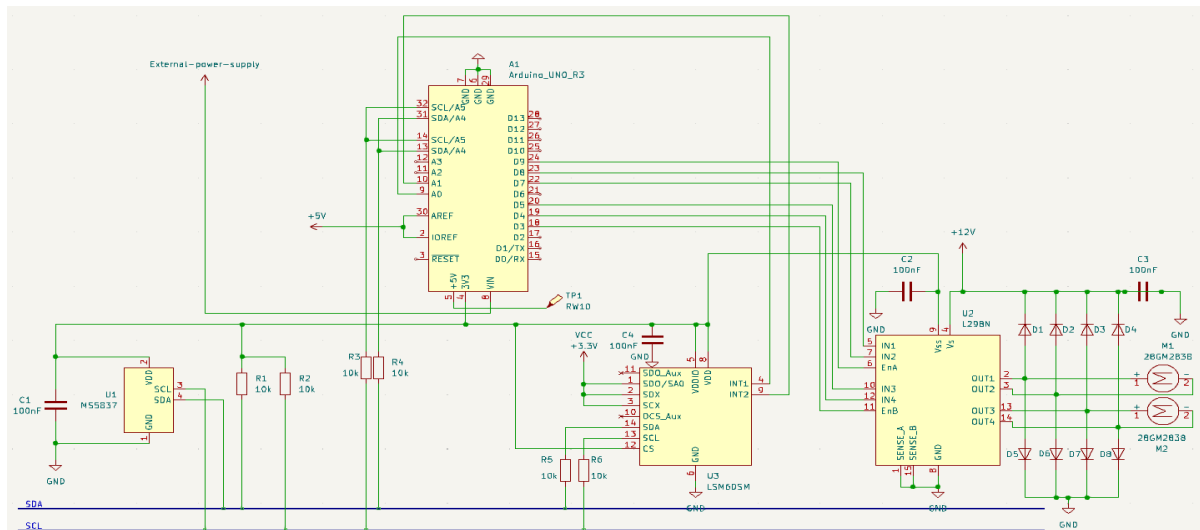
### 2.6. Control signal communication design

LabVIEW is used to develop the water surface control system program, using a wired serial connection to achieve the Arduino as the core of the underwater control system and LabVIEW communication.

Underwater control system's core Arduino digital interface pin 0 is used for receiving (RX), pin 1 is used for sending (TX), and uses Serial library function to establish Arduino serial communication. Serial.begin function is used to set the serial port baud rate, and LabVIEW's VISA Configure Serial Port node echoes the requirements of the serial port baud rate at the same time. In the Genie No. ROV system communication baud rate is set to 9600 bit/s; Serial.available function is used to determine whether the serial port receives data; Serial.read function is used to read the serial port data into, and LabVIEW's VISA Write node corresponds to; Serial.print function is used to output the data from the serial port, the data for the variable or string, which is corresponded to LabVIEW's VISA Read node. The power supply part will be realised by connecting a cable to the water that can transmit both power and data [16].

### 2.7. Overall circuit diagram design

The following is a schematic diagram of the overall circuit connection: the power supply for the Arduino motherboard will be done by connecting a cable from the ground that can do both power supply and data transmission. The overall circuit design diagram is shown in the Figure 6.



**Figure 6.** Overall circuit design diagram (Picture credit: Original)

### 3. Discussion

This thesis is mainly for the circuit design of the underwater detection robot to give the circuit design scheme of the robot, according to the function of the designed robot needs to select the corresponding devices and sensors of the model and performance indicators, and at the same time according to the parameters of each part of the device work when the overall circuit design schematic diagram of the robot is given. Considering that the current marine ecological environment is very harsh, and all kinds of radioactive elements and radiation rays underwater are very harmful to the human body, designing an underwater detection robot is a very necessary task. Moreover, since the circuit scheme designed in this paper corresponds to an underwater detection robot with a specific detection target, the circuit scheme designed in this paper is simpler than many previous studies and does not need to detect many substances that other robots have to take into account. However, the proposed circuit design scheme is only a theoretical result based on previous research and has not been examined in detail, so the feasibility of the scheme still needs to be verified by experiments in the future work. At the same time, there are still areas of improvement in this circuit design scheme, such as whether the protection of each part of the sensors and devices is in place, whether there is a more reasonable circuit connection, etc. These questions also need to be considered. In the future, it can be considered to design an underwater exploration robot with more varied functions, which can complete more complicated exploration work, so that human beings can understand the marine environment in a more convenient and safer way, which can also make use of the advanced technology of human beings, and provide a more favourable ecological environment for the future generations.

### 4. Conclusion

In carrying out the hardware circuit design of the underwater detection robot using Arduino as the design core of the underwater system and LabVIEW as the design core of the water system, the design of the general circuit framework of the underwater robot is given, which can basically realise the initial design function --- autonomously locate itself underwater, maintain the balance of the underwater attitude, and then carry out the detection of the pollution, and then transmit the detected data transmission to the ground. However, the proposed circuit design scheme is still a theoretical result, based on the operating parameters and interface requirements of various devices, and has not been verified in practice, so the feasibility of the scheme still needs to be verified. In addition, it will need to be continued to improve the circuit design to make the function of the underwater robot more perfect, and make underwater robots perform better. For example, the acquisition accuracy of the underwater robot can be improved, or the selected devices can be optimised to make its parameter indicators more in line with the requirements, so as to achieve the purpose of perfecting the function and improving the performance of the underwater robot.

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