DC Servomotor Module for Robotic and Mechatronics Education

Katsuhiko Inagaki
Department of Applied Computer Engineering, Tokai University
4-1-1 Kitakaname, Hiratsuka, 259-1292 Japan

and

Nurul Izzati binti Azlizan
Department of Applied Computer Engineering, Tokai University
4-1-1 Kitakaname, Hiratsuka, 259-1292 Japan

ABSTRACT

In this study, we propose a new type of DC servomotor module. This module is designed for use on the education in mechatronics and robotics. Although, RS servo is usually used for these purpose, but it has several demerit. Thus, we have developed a new type of one. In this paper, the specification of the servomotor module is discussed.

Keywords: Mechatronics Education, Robotics, Teaching materials, Servo motor module

1. Introduction

In the field of mechatronics and robotics, many kinds of knowledge are required. The following items are mainly the required knowledge for mechatronics and robotics.

- Mechanical design and its assembly
- Electrical circuit design and its assembly
- Sensors and actuators
- Computer interface
- Software design and its programming
- Control theory
- Kinematics and dynamics

However, to build up a high performance real mechatronics system, not only knowledge is required, but also various skills and techniques. On this point of view, experiment and practice are very important for mechatronics and robotics education.

In recent years, as a method for teaching these the above mentioned skills above, new practical education methods have been reported.[1]-[4] In these reports, robot contest is applied as the method of education that is contributed to the improvement of student's motivation. However, to perform this type of education, teachers must put a lot of effort to prepare the teaching materials. Thus, it is important to develop many kinds of teaching materials to reduce the amount of effort.

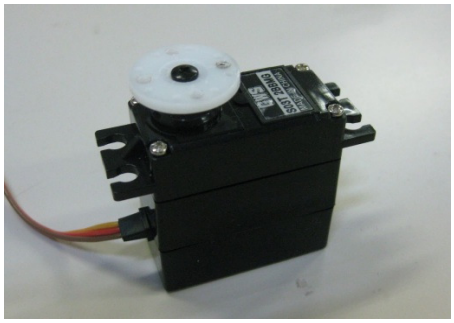

Fig.1 Conventional type of RC servo

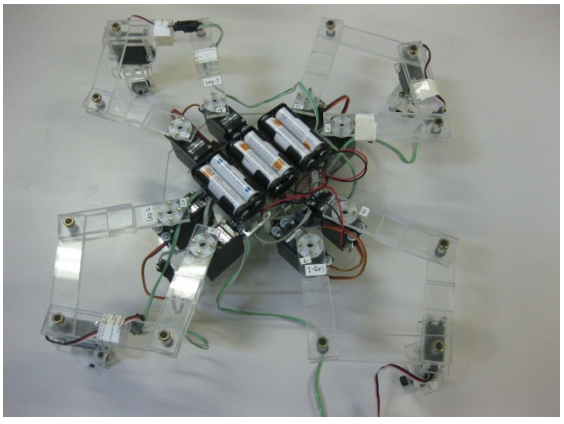

Fig.2 A sample of legged robot by using RC servo

From this point of view, RC servo (Radio Control servo

motor) is very useful. (**Fig.1** shows the typical example of an RC servo.) Although RC servo is developed for hobby use such as radio control car, it is very useful as an actuator of a robot such as a small size humanoid robot and a multi-legged robot. For example **Fig.2** shows a wheel-legged robot which is developed in author's class. This robot consists of 12 RC servos. RC servo has several merits as follows.

1) It is possible to create robot system at a low cost, because RC servo is mass-produced for hobby use.
2) Feedback loop for position control is not required for user, because all the items for positioning control (actuator, reduction gears, position sensor, power amp and circuit for feedback control) are included in the RC servo.

On the other hand, RC servo has the following demerits.

1) Information between RC servo and commander is only positioning signal.
2) Control mode is limited to position control, and gain tuning is not allowed.
3) Control period is too long. (About 20[ms])
4) Range of motion is limited, about 120 [deg]. (This demerit prevents the RC servo from being used as an actuator of wheeled robot.)
5) Since number of interface is proportional to the number of RC servo, multi DOF system may have wiring problem.

In view of the above-mentioned problem, we have tried to develop a new type of DC servomotor module which has the following noteworthy points.

1) Realizing low cost module with motor for hobby use
2) Limitless range of motion
3) Employing one chip microcontroller for measuring and control
4) Employing motor driving circuit that has excellent linearity
5) Realizing low cost position sensor with slit disc made of film
4) Possible to use two types of interface, USB and serial bus type communication

2. Elements for DC Servomotor Module

2.1 DC motor with backlash free gearbox

To use the DC motor with gear box for hobby use (**Fig.3**) is one of the most effective way to cut down the cost. However, this type of motor is not suitable for position control, because backlash of the gearbox is very poor. As the result of simple experiment, we measured about 20[deg] range of backlash. This performance is not applicable in the use of precision control such as robot joint.

To overcome this problem, we have developed a new method to reduce the backlash of the gear box. **Fig.4** shows the outline of the DC motor module with backlash free gearbox. In our method, one module has two motors and two gearboxes for single actuation.

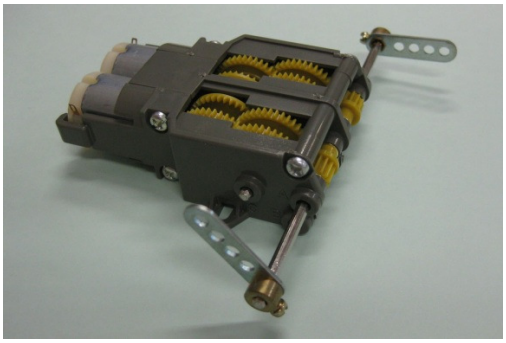

Fig.3 DC motor with gear box for hobby use

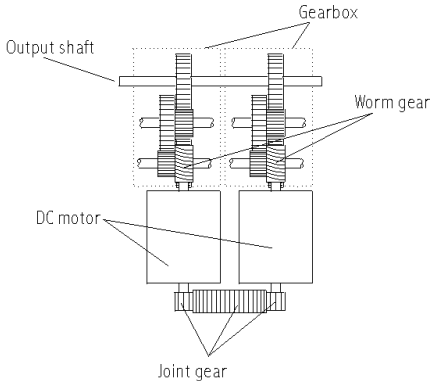

Fig.4 Backlash-free motor module

The both sides of motors are connected to each other. One side is connected by the *output shaft* of gearbox, and the other side is connected by the *joint gear*. Before connecting

of the *joint gear*, the two motors must be rotated to the opposite direction to get pressurization. By the pressurization, the *output shaft* has no backlash. It is very simple, but it is effective enough to kill the backlash.

2.2 Motor driver circuit

In the case of the small size DC motor, we can get conventional motor driver IC form the market. However, such kind of a driver has the following problems.

1) Linearity between voltages to motor speed is poor.
2) The range of dead band is wide in low speed.
3) Energy efficiency is low.

To solve this problem, we have applied a new type of motor driver with several discrete parts as shown in **Fig.5**. It is well known that H-bridge circuit driven by PWM (Pulse Width Modulation) signal is one of the efficient drive circuits for DC motor. Conventional type of such type of motor driver uses only one PWM signal. However, our original driver uses two kinds of PWM signal that have another duty factor. If we want to drive the motor with x [%] of maximum power ratio, duty factors for two PWM D_1 and D_2 signal can be decided by the following equations.

$$D_1 = \frac{x}{2} + 50\,[\%]$$

$$D_2 = \frac{x}{2} - 50\,[\%]$$

Fig 6 shows the PWM signals in the case x = 50 [%] and **Fig.7** shows the H-bridge circuit for the PWM signals. During the period-B in **Fig.6**, left-high side and right-low side FETs are turned on. Thus, driving current flows in the direction of the arrow in **Fig.7**. Then, during the period-A and C, voltage from the power source is not applied, but terminals of the motor is not opened, because both of the low side FETs are turned on during period-A, and both of the high side FETs are turned on during period-C. This fact causes good energy efficiency for the motor driver.

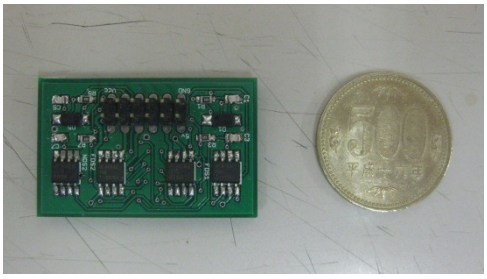

Fig.5 Motor driver for the modules
(Note: Japanese coin whose diameter is 26.5 [mm] is shown in right side for size reference)

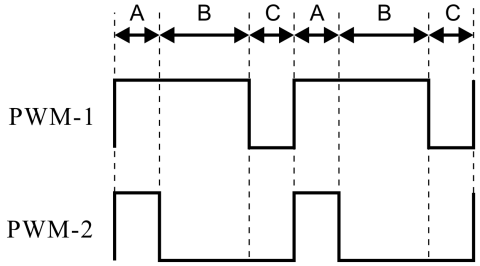

Fig.6 PWM signals to drive the H-bridge

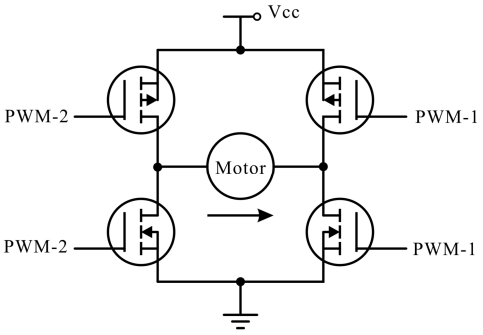

Fig.7 H-bridge circuit for motor drive

2.3 Position sensing

In the case of RC servo, potentiometer is used as a position sensor. This makes it possible for RC servo to be available at a low cost, but this causes limitation of rotational range. Rotary encoder can solve the limitation problem, but it costs a lot. The biggest reason why encoder is expensive is because of its slit disc. Usually, slit disc is made of metal and the slit is processed by laser to get a high resolution.

Thus, to reduce the cost of the slit disc, we have made simple disc by using the inkjet printer and film. This method cannot realize high resolution. However, instead of attaching the

disc to the output of the gearbox, the disc is attached to the shaft of the motor to obtain higher resolutions. Usually, this method has no meaning, since back lash is influenced to the resolution. However, this method is effective enough in our case, because backlash does not exist as mentioned before.

2.4 Microcontroller

As mentioned before one chip microcontroller is applied to our module. The following matters are the roles of the microcontroller.

1) To generate two PWM signals for the motor driver circuit
2) To count the signals from the rotary encoder
3) To receive the position control signal from the host by use of two kinds of communication methods.
4) To realize software based feedback control

The software to realize these matters are described by the assemble software to realize high control frequency. As the communication method to connect the servo module and host controller such as personal computers, the module has two types of communication methods, one is USB and TWI (Two-wire Serial Interface). USB is used to connect the module to the host computer directly. On the other hand, TWI is used to connect among number of servo modules, because TWI is designed to interconnect many numbers of different devices. Therefore, with the combination of the USB and TWI, it is possible to build up a system that has many numbers of servo modules such as a robot system with multi-D.O.F.

3. Benchmark of test module

Fig.8 shows the prototype model of the DC servomotor module for benchmark. This is connected to the PC by using the USB. **Fig.9** shows the result of the experiment of the positioning control. The target trajectory is sin wave, and we can get enough useful result.

4. Conclusion

In this study, we have proposed a new type of DC servomotor module for robotics and mechatronics education. The servo module can perform endless rotation, since position sensor is not potentiometer. Thus, this module can be applied to many kinds of systems. Typically, it can be used for actuator for wheeled robot.

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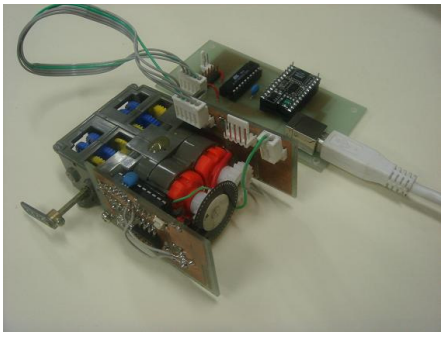

Fig.8 Prototype model of DC servomotor module

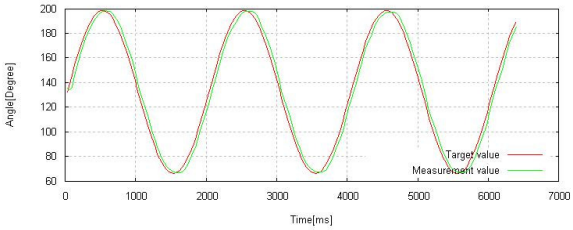

Fig.9 Result of positioning control