한국공작기계학회 2004 추계학술대회 논문집 pp.474~479

# 로봇 제어를 위한 시스템의 하드웨어 구성

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# THE SOLUTION OF HARDWARE OF ROBOT CONTROL SYSTEM)

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Abstract

This paper presents an economical solution of the control system of robot, which is widely applied to sophisticated robots. The proposed control system is built on a foundation that is combined between driver motor, PC controlled servo-motor control card, and driver software. The solution had been applied to design hardware of controlled 6-DOF (Degree Of Freedom) robot. The controlled system is used to control VML Robot (Vehicle Mechatronic Lab). Addition, because of flexibility of the solution, the controller can be suit with widely robots that used servo-moto.

## 1. Instruction

Today, application of industry robot is disseminated in factories. Because of fast-growing in high-tech and computer, the robot may be performs their functions exactly, quickly, and intelligently. However, some impediments occur during applied as:

- Cost price is too high for robots and control system.
- Closed system investigation into robot become difficultly.
- The control software is limited.
- Modify its functions is difficultly.

By reason, the existing system inappropriate to researched laboratory. Thereby, a new idea, which is new design of control system to VML robots, is develope.

## 2. The robot and the controller

The robot control system was designed for VML robot type six DOF robot. Fig.1, show the VML robot. Focusing on the actuator and sensor of the robot hardware, each axis of the robot has its own servo motor, encoder and one home-position sensor.

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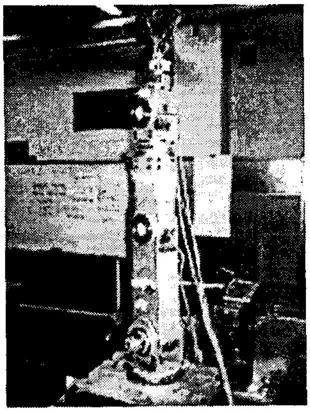

Fig. 1 VML Robot

Table 1 Motor parameter of the robot

| Join | Motor | Motor Parameter | | | |
|---|---|---|---|---|---|
| 1 | SM60-106-600114EI<br>SANYO MOTOR | 70W | 24V<br>Ip=4.3A | N=2400rpm<br>T=2.8kg | 200P/R |
| 2 | SM60-106-600114EI<br>SANYO MOTOR | 70W | 24V<br>Ip=4.3A | N=2400rpm<br>T=2.8kg | 200P/R |
| 3 | QT-1401-C<br>INLAND MOTOR | 38W | 22.3V<br>Ip=9.78A | N=4100rpm<br>T=0.915kg.cm | 60P/R |
| 4 | QT-1401-C<br>INLAND MOTOR | 38W | 22.3V<br>Ip=9.78A | N=4100rpm<br>T=0.915kg.cm | 60P/R |
| 5 | QT-1401-C<br>INLAND MOTOR | 12W | 18.3V<br>Ip=6.11A | N=4250rpm<br>T=0.915kg.cm | 60P/R |
| 6 | QT-1401-C<br>INLAND MOTOR | 12W | 18.3V<br>Ip=6.11A | N=4250rpm<br>T=0.276kg.cm | 60P/R |

The structure of the robot controller shown in Fig. 2

The hardware of robot controller consist of a personal computer, two PCL-832 3-axis servo motor control cards, six driver motor and one power supply.

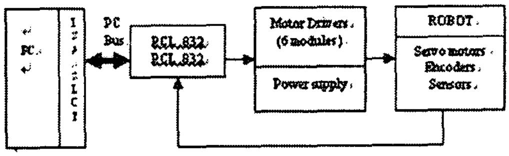


Fig 2. Describes the structure of the robot controller

## 3. PCL-832 3-axis servo motor control card

The PCL-832 card is produced by Advantech Co., Ltd.

The PCL832 3-axis Servo-motor Control Card turns your IBM PC or compatible computer into a sophisticated position controller. The card's custom ASIC implementation provides high performance at an affordable price. The PCL-832 uses digital differential analysis techniques to implement position control. Each axis has its own position control chip,

allowing completely independent control of up to three servo motors. A special synchronization circuit synchronizes all three axis. The card can supply a simulated tachometer output to the servo motor driver. This signal makes a tachometer unnecessary in some applications, reducing overall system costs.

There are following features:

+ Independent 3-axis servo control.
+ Fully continuous closed-loop P
+ offset controller.

Industry-standard two-phase index position encoder interface.

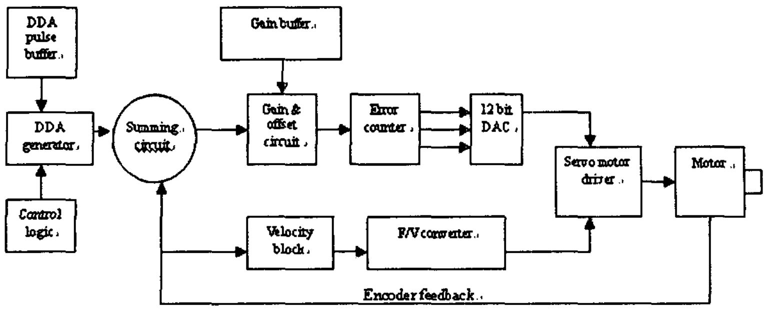


Fig 3. Closed-loop position control

The PCL-832 uses proportional closed-loop position control to obtain reliable and accurate results. It featuresan internal velocity feedback loop and offset techniques to compensate for the steady-state error that is caused by using small values on the P controller.

The functional block diagram of the PCL-832 motion control card is shown below:

The DDA generates continuous command pulses through CMD+ and CMD- channels (not shown on the *Fig.3*). These command pulses are fed into a summing circuit, together with the pulses generated by the servo motor encoder device. The summing circuit determines the difference between the two signals. The computed result is then fed into the *P* pulse-offset controller. The *P* pulse-offset controller, which has programmable gain (*Kp*), outputs pulse numbers. This pulse is fed into the error counter, which drives the DAC chip in real-time. A velocity block is provided in the motion control chip. Its purpose is to add a velocity feedback loop in the whole system through a frequency-to-voltage (F/V) converter. This internal loop improves the motion dynamics of the servo motor system.[5]

## 4. Driver motor

Block diagram of motor driver (shown in Fig. 4) consists of: H-Bridge, PWM, Transfer function

+ Single-ended or differential encoder interface inputs.
+ x1, x2, x4 quadrature feedback input.
+ 12 bit analog output with ± 10 V range.
+ Built-in F/V converter.
+ Easy programming from C and other high-level languages.
+ 3-axis linear interpolation.
+ 2-axis circular interpolation.
+ Half-size AT (ISA bus) add-on card.[5]

module. H-Bridge outputs the signal to control motor. The H-Bridge regulates motor speed by controlling the average current applied to the motor. Thepulse-width modulated signal from the PWM controls the amount of time each pinof the H-Bridge is on or off. The longer the on time, the more average current is applied, and the faster the motor spins. The transfer function module is the PID controller. This module receives signal from PCL-832 card and process them. The processed signal is transmited to PWM to forms PWM pulse.


fig. 4 Driver motor diagram

### 4.1 Transfer function module

This transfer function is PID controller

$$G(s) = K_P + \frac{K_I}{s} + K_d \quad (1)$$

where $K_P, K_D$ , and $K_I$ are real constants.

since the first term is a **Proportional** gain, the second an **Integral** term, and the third a **Derivative** term. This sum can be implemented by adding an additional input resistance to the circuit shown in Fig. 5.

By making the sum negative, the negative gains of the proportional, integral, and derivative term implementations are canceled, giving the desired result shown in Fig. 5

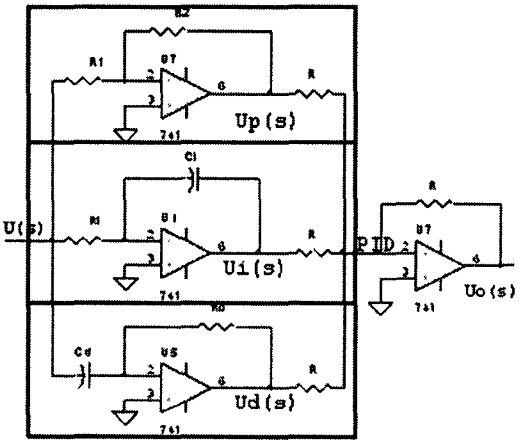


Fig 5. Transfer function module

The transfer functions of the components of the op-amp circuit in Fig. 5 are

Proportional: $$\frac{U_p(s)}{U(s)} = -\frac{R_2}{R_1}$$ (2)

Integral: $$\frac{U_I(s)}{U(s)} = -\frac{1}{R_i C_i s}$$ (3)

Derivative: $$\frac{U_D(s)}{U(s)} = -R_d C_d s$$ (4)

The output voltage is

$$U_0(s) = -\left[U_p(s) + U_i(s) + U_d(s)\right]$$ (5)

Thus, the transfer function of the PID op-amp circuit is:

$$G(s) = \frac{U_0(s)}{U(s)} = \frac{R_2}{R_1} + \frac{1}{R_i C_i s} + R_d C_d s \quad (6)$$

By equating Eqs. (1) and (6), the design is completed by choosing the values of the resistors and the capacitors of the op-amp circuit so that the desired values of *KP*, *KI*, and *KD* are matched. The design of the controller should be guided by the availability of standard capacitors and resistors.

It is important to note that Fig. 5. is just one of many possible implementations of Eq.(1). For example,it is possible to implement the PID controller with just three op-amps. Also, it is common to add components to limit the high-frequency gain of the differentiator and to limit the integrator output magnitude, which is often referred to as anti wind-up protection. One advantage of the implementation shown in Fig. 5. is that each of the three constants *KP*, *KI*, and *KD* can be adjusted or tuned individually by varying resistor values in their respective op-amp circuits.

**4.2 Pulse width modulation**

The PWM (pulse width modulation) drives the H-Bridge that controls the speed of the motor. As shown in Fig. 6, the PWM duty cycle ranges from 0 to 100%, where 0 indicates a total off and 100 indicates a total on. The higher the duty cycle the more energy the motor receives, and the faster it rotates. Depending on the desired reaction of the motor, we design the frequency of PWM module.

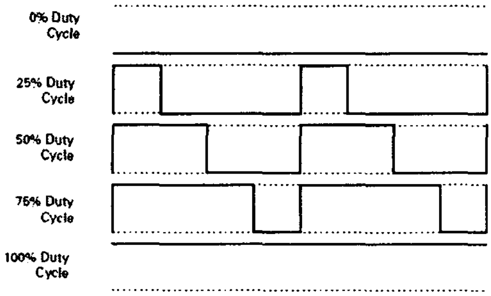


Fig 6. PWM pulse

PWM configurations use one IC TL494.

The TL494 is used for the control circuit of the PWM switching regulator. TheTl494 consists of 5V reference voltage circuit, tow error amplifiers, flip flop, an output control circuit, a PWM comparator, a dead time comparator and an oscillator. This device can be operation in the switching frequency of 1 KHz to 300 KHz.

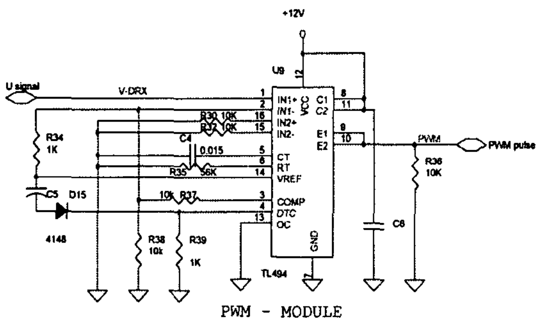


Fig 7. Pulse width modulation

### 4.3 The H-Bridge output controls the motor

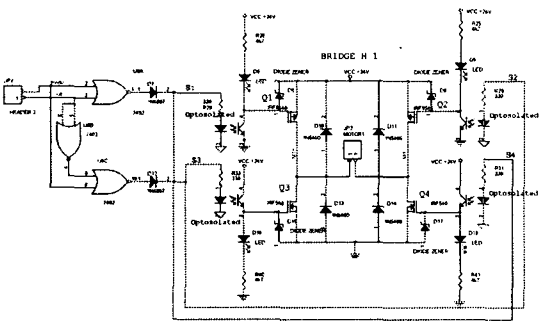


Fig 8. H-Bridge module

The output for driving the gate drive transformer(s) is rail-to-rail, i.e. 0V to 24V (or what you have). The only functional weakness of the circuit is that the mosfets warm up at high drive frequencies, somewhat independent of the load. Heating is caused byshort conduction overlaps when the mosfets are switched/toggled (shoot-through current), which means the heating is proportional to the drive frequency. In any case, to operate above 200 KHz you should use small heatsinks for the mosfets. The zeners D1-D4 ensure that one mosfet does not yet reach its threshold voltage while the other mosfet is still fully enhanced. This adds a bit of dead time to the switching and reduces the shoot-through. A bad side effect of the zeners is that the mosfet gate voltage is reduced and they might operate outside the triode region, causing some additional warm-up. Optosolated to protect logic circuitry from motor electrical spikes.

## 5. conclusion

In this paper, the presented proposed control system has the features: 19 amp capability, 75 volt maximum, internal PWM generation. As previous results, the control system has proved its good stability needed for high performance robot. The change ability of the controller's configuration for different types of robot. The manufacturing cost is lower than other system. On the other hand, the present of this controller helps communication between users and robot become the motor by flowing through Q1 and Q4 for one direction or Q2 and Q3 for the opposite direction. The built-in direction bit of the H-Bridge controls the current flow through the different mosfets..

more easier by using programming language such as C++, visual C, Delphi which will be a very promising research direction in the near future.

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