Development and application of multi servo motor system of environmental monitoring equipment based on DSP control

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Abstract: This paper provides a solution of synchronous control of 10-way Panasonic A6 servo motor using DSP chip (TMS320F28379D), which can obtain good dynamic performance and motion position control accuracy. The system uses PID control algorithm to realize intelligent control of position and speed of ten servo motors, and uses database to record the dynamic data of speed, time, distance and power of each servo motor. It can be used in the driving device of environmental monitoring equipment.

1. Introduction
Environmental protection has become an important aspect of the national development strategy. One of the important contents in the work of environmental governance is to monitor and effectively control the excessive discharge of pollutants from production enterprises. In 2007, the environmental protection data acquisition and transmission equipment began to be used at the source of pollution to monitor the pollutant emission concentration and amount online. The Ministry of environmental protection has issued a series of ministerial standards, such as data transmission standard for online automatic monitoring (monitoring) system of pollution sources (HJ/t212-2005), technical requirements for online automatic monitoring (monitoring) data acquisition and transmission instrument of pollution sources (hj477-2009). In 2013, relevant departments began to gradually realize the transformation from end-to-end monitoring to whole process monitoring of key pollution sources under state control. This equipment can comprehensively collect the import parameters, process parameters, and electrical parameters (current, voltage, frequency, speed) that affect pollutant discharge, and comprehensively monitor the operation of corporate governance facilities and pollutant treatment combined with terminal monitoring data The results and discharge amount shall be determined to determine the rationality, authenticity and acceptability of pollutant discharge monitoring data. In order to achieve the whole process monitoring, the multi-channel control signals must be completely consistent. Therefore, a multi-channel servo motor control system based on DSP control is developed, which can be widely used in the driving unit of environmental monitoring equipment. [1] [2] [3] [4]

2. Overall design of system
The 10-way servo motor system is controlled by three loops: speed measuring loop, position loop and torque loop, wherein the non-speed measuring loop of sending signal of position loop receives signal, the non-torque loop of sending signal of speed measuring loop receives signal, and the system control diagram is shown in Figure 1. The system compensates the external interference with robust PID control, improves the dynamic performance, and eliminates fluctuation and the oscillation occurred during motor positioning [5] [6].
2.1. Hardware design module
The 10-way servo motor control system includes main control chip, USB module, bus module, servo drive, PWM output, DAC module, ADC module and power module.

2.1.1. DSP control module
DSP chip is TMS320F28379D (32-position floating-point microcontroller unit) with new dual-core architecture, the frequency of each core is 200MHz, the capacity of Flash memory is 1MB, and there are 4 analog-digital converters (ADC) to control 24 external channels and 8 digital analog converters (DAC); it has enhanced control peripheral, 24 PWM channels, 6 eCAP modules and 3 eQEP modules, as well as standard SDFM data filter. In addition, USB2.0 communication is adopted.

2.1.2. IO bus extension module
TCA6424 is low-voltage 24-position I2c and SMbus I/O extender with interrupt output reset and configuration register.

ADG3308 is a two-way level translator, with 8 two-way channels. The internal structure of device can realize two-way level switch and be used for multi-voltage digital system. The main function of system is the data transmission between DSP controller and high-voltage device.
2.2. Servo motor

Servo motor is a control motor applied to motion control system, and the output parameters include position, speed, acceleration or torque. Servo motor can control the speed, realize accurate positional accuracy and convert voltage signal into torque and speed to drive the controlled object. The speed of servo motor rotor, used as the actuator in the automatic control system, is controlled by the input signal with quick reaction and featured with small electromechanical time constant, high linearity and pickup voltage, and can convert the received electric signal into angular displacement or velocity output of motor shaft. Currently, there are two kinds of servo motors: brushless DC and AC servo motors. The type of servo motor in this paper is Panasonic A6MBDLT25SF, whose drive waveform is trapezoidal wave, and such type belongs to brushless DC motor (also referred to as permanent magnet brushless synchronous motor). Input voltage: 200-240V; 0.4KW, maximum current: 20A; frequency: 250HZ; 16,000 times at most within 1s; speed: 3000r/min; torque: 1.27N; speed response of drive: 3.2KHZ; absolute encoder precision of motor: 23bit (8/Mp/r); the shortest communication period: 0.0625ms; with the functions of high-precision position comparison and infinite operation absolute type [7] [8].

Figure 3  IO Bus Extension Diagram

Figure 4 Mechanical Characteristic Curve of Panasonic A6 Servo Motor
3. Software design
After start-up, the multi-core DSP lower machine will initialize the DSP multi-core and in-disc resource (such as timer, PWM and CAP), drive the network module, initialize the extended function modules (motor control, power detection and ADC sampling), realize authority control and enter the system task for dispatching applications [9] [10] [11].

Data shall be encapsulated and encrypted before sending. The received data shall be decrypted and analyzed, and realize control or functions according to the analysis content.

The software carries out multi-core DSP processing according to the command (obtained from data analysis) sent from the upper machine and realizes high-speed high-efficient real-time contro.

Some programs are as follows:

```cpp
void Widget::setDcDataSlot()
{
    int i,j;
    int dval;
    int index;
    int vmin,vmax;
    // Data filtering
    index = 0;
    if(usb.dcCnt < 3)
    {
        // Average filtering
        if(usb.dcCnt)
        {
            for(i=0; i < 14; i+= usb.dcCnt)
            {
                dval = 0;
                for(j=0; j<usb.dcCnt; j++)
                {
                    dval += usb.dcBuf[j][i];
                }
                usb.dcResBuf[index] = (((double)(dval))/usb.dcCnt)*3*dcScaleDef[index]/4096;
                index++;
            }
            usb.rxSize = index;
        }
    }
}
```
Figure 5  Software Design Flow

```c
else
{
    // Deburring + average filtering
    for(i=0; i < 14; i++)
    {
        dval = usb.dcBuf[0][i];
        vmin = usb.dcBuf[0][i];
        vmax = usb.dcBuf[0][i];
        for(j=1; j<usb.dCnt; j++)
        {
            if(vmin > usb.dcBuf[j][i])        vmin = usb.dcBuf[j][i];
            if(vmax < usb.dcBuf[j][i])        vmax = usb.dcBuf[j][i];
            dval += usb.dcBuf[j][i];
        }
    }
```
usb.dcResBuf[i] = (((double)(dval - vmin - vmax))/(usb.dcCnt - 2))*3*dcScaleDef[i]/4096;

this->test.dcFlag = 1;

4. Communication protocol development

Due to the large amount of data transmission, USB communication is transmitted in BULK mode, network communication is transmitted in UDP mode, and both are communication without verification. To guarantee the reliability and accuracy of data transmission, data are transmitted and verified through data transmission protocol.

4.1. Communication mode

To facilitate bulk data transmission, USB communication is transmitted in BULK mode according to the standard protocol USB2.0. To realize quick transmission of bulk data, the network communication is transmitted in UDP mode according to TCP/IP Ethernet protocol.

4.2. Data transmission protocol

Since the data transmitted by the upper and lower machines have different purposes, data transmission protocol is developed to distinguish the specific purpose of data and control the reliable transmission.

Message format: message header + message content + verification
Message header: the first to sixth bytes of data transceiving, with fixed format and length.
【Command】 + 【status】 + 【packageCnt】 + 【size】
[Command], the first byte of data, designating the data purpose
[Status], the second byte of data, marking the current data transmission state, controlling the transmission, data verification and answer. The receiving end resends the control data and judges whether the data are transmitted according to the state.
[packageCnt], the third and fourth bytes, data index during big data transmission.
The application program can restore data sequentially according to the index.
[size], the fifth and sixth bytes, excluding the lengths of first 6 bytes and the last byte.
Message content: 【Content】 , the seventh to sixty-three bytes (network transmission: 7-1,455), binary coding data.  【checksum】 Verification:  【checksum】
Verification:  【Content】 , the byte next to the last byte, verify whether the data transmission is correct.
The message is encapsulated as follows:
【Command】 + 【status】 + 【packageCnt】 + 【size】 + 【Content】 + 【checksum】
Length of message transmission: 6 + size + 1

4.3. Data encryption and decryption

Considering the data security, the data between main controller (PC upper machine) and real-time measuring and controlling device (multi-core DSP lower machine) are transmitted through ciphertext. The transmitted data shall be encrypted with encryption algorithm and encapsulated for sending. The received data shall be decrypted with decryption algorithm, analyzed and operated according to the analysis content.

4.4. Data encapsulation and analysis

Data encapsulation: the encrypted data is encapsulated and converted into the message format of data transmission protocol for sending. Data analysis: the decrypted data shall be analyzed and managed to realize operation and functions according to the analysis content.
4.5. System authorization
To control the copyright of system software and the using time of system, authorization management is carried out through authorization document. The authorization document is generated with three-layer authorization algorithm and realizes authorization management of system software. First-layer authorization algorithm: collect the serial number of PC computer CPU, hard disk and mainboard, the UID of DSP chip and the ID and control time of connected module for converting data and generating the first-layer ciphertext. Second-layer authorization algorithm: scramble the first-layer ciphertext with random distribution algorithm, and convert the second-layer data to generate the second-layer ciphertext. Third-layer authorization algorithm: realize MD5 conversion of second-layer ciphertext, scramble the converted data with random distribution algorithm, and generate the third-layer ciphertext and authorization document.

5. Conclusion
The control core of ten-way servo system is the precise control of DSP controller to the servo motor and based on the robust PID algorithm. The DSP digital processor system has superior expansion performance, strong anti-interference and high control accuracy. Meanwhile, this paper explores the setting of parameters and initial values with algorithm and successfully designs the ten-way servo motor system which has high control accuracy and good application value of environmental monitoring.

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