Development of Multiple-Axes Intelligent Servo Amplifier "PQ"

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1. Introduction

The development of servo actuators for factory automation (FA) has focused on small size, long life, low cost, high performance, functionality and safety. The motors used in such servo actuators have been developed accordingly: the range of capacity and that of speed have been increased, and also many different types of motors have been developed, including the now-practical linear motor as well as the conventional rotary type motor.

Development of the servo amplifiers that drive such motors has also progressed, focusing on small size and low price in addition to the diversification of power supply specifications, trend toward energy conservation, and improved functionality and performance to control the various types of motor. For the user, servo amplifiers are used for either one axis (called "single axis" in this paper) or used for multiple axes (called "multiple-axes" in this paper) depending on the structure of the actual machinery in which the servo amplifiers are installed. However, servo amplifiers are generally used in multiple-axes applications. Previous attempts to develop general purpose multiple-axes servo amplifiers have failed due to the lack of standardization of the interface and performance. Together with the trend toward open architecture servo systems, the interface and multiple-axes control functions have gradually been standardized and reached a practical stage.

We report here on the development of the multiple-axes intelligent servo amplifier "PQ" suitable for various applications.

2. Background of Multiple-axes Servo Amplifier Development

The "multiple-axes servo amplifier" refers to a conventional servo amplifier that is developed for a specific piece of machinery that has a limited number of axes and capacity in order to offer reduced size or lower cost through integration or combination into a single-body structure. In the conventional multiple-axes servo amplifiers, a dedicated servo amplifier and controller had to be developed and the software was also complicated, thus prolonging the development period. Where users have not had enough time to develop the controller, it has been the general practice to purchase a controller from a controller maker. But since the architecture of controllers has not been open, users have been obliged to purchase both the servo motor and the multiple-axes servo amplifier made by the same maker as that of the controller. This has restricted the user's choice. Users have been forced to configure a multiple-axes system that contains general-purpose single-axis servo amplifiers even for multiple-axes applications, and so the inherent merits of the multiple-axes servo amplifier have not been realized in many cases. Users need a multiple-axes

servo amplifier that has an open architecture and that offers advantages when configured into a system.

3. Merits and Technical Problems of the Multiple-axes Servo Amplifier

The multiple-axes servo amplifier can offer many merits that a single-axis servo amplifier cannot, by efficiently combining the structures and capacities depending upon the target machinery to be used. However, there are still several technical problems that must be solved before the multiple-axes servo amplifier can be used easily. The merits of the multiple-axes servo amplifier and its technical problems are discussed below.

(1) Space-saving and low cost

Miniaturization and low cost can be realized by using the same power supply, control circuit and mechanical parts in common for the multiple axes. Recent developments in microprocessor technology allow us to control multiple axes with high-speed communication internally and externally.

(2) Wire-saving

The wirings between the amplifiers of the respective axes and those of the host controllers, that are required when two or more single-axis servo amplifiers are used and that are laid outside of the amplifiers by the user conventionally, can be eliminated by the single-body structure of the multiple-axes servo amplifier. However, the shape and combination of amplifier are limited by mechanical aspects when a backplane is used.

(3) Energy-saving

When a machine is used in a multiple-axes application, there will be almost no chance in which all axes perform the same motion. This means that energy transfer occurs between the amplifiers that are connected to the common DC main power supply circuit, when power running and regeneration running are executed at the same time. Therefore, energy-saving operation of the machine becomes possible.

(4) Trend toward open architecture

As the open architecture is further promoted, the servo amplifier is anticipated to develop in two different directions: one is toward the PWM amplifier in which the servo amplifier has merely a PWM inverter function, while the other is toward the intelligent amplifier (AI amplifier). Control of amplifiers of the former type depends on the host system (controller, etc.) so the controller inevitably becomes expensive in order to realize high performance and many functions. Amplifiers of the latter type ultimately should have no dedicated board (i.e., no motion card) by connecting the servo amplifiers and PC (personal computer) to the field area network. An open-architecture interface which is compatible with the multiple axes control function must be required.

4. Development Concept of "PQ" Amplifier

The development concept was to create a compact, low-price multiple-axes amplifier according to the open interface specifications, based on the multiple interface declaration announced in 1996.

To solve the technical problems of the multiple-axes amplifier, the following design policy was adopted.

(1) Small-capacity amplifiers and middle- and large-capacity amplifiers have contradictory requirements in view of their structure, and so shall be separately designed as two different product groups to fully utilize their respective strengths.

(2) The functions and performances must be worldwide marketable. The graphical

design must make the product attractive.
(3) The total cost of the entire multiple axes system must be reduced by including in the amplifier various useful functions for the host system.

5. Characteristics of "PQ" Amplifier

  "PQ" servo amplifier that was developed under this design policy, marks the first step toward the intelligent servo amplifier. This product is not only utilizes the merits of the entire system, but also is compact and low cost like the conventional multiple-axes amplifier. The amplifier enables to support the open architecture by using SERCOS world-standard field bus specified by the IEC standard. Thus a multiple-axes amplifier system, such as only realized in the limited system so far, will be able to be built in various case. The detailed features are as follows.
(1) Development of two series of multiple-axes amplifier
  Two types of "PQ" series were developed: the multiple-axes single body intelligent amplifier ("PQ" Type R, photo 1), and the multiple-axes distributed type intelligent amplifier ("PQ" Type M, photo 2). These two types of product enable miniaturization for small-capacity products, and wide variation for middle- and large-capacity products.
  "PQ" Type R has been made compact and low cost by integrating all units of the amplifiers into a single body that can be mounted in a rack. Motors of up to 1 kW x 4 axes can be connected. The distributed type multiple-axes intelligent amplifier "PQ" Type M consists of a power supply (PS unit), multiple axes control block (MC unit) and drive block (AMP unit). The drive block can be freely configured in different units of different capacities ranging from 1 kW to 22 kW, and up to the four axes, i.e., the distributed type offers great flexibility when configuring a system. Wirings between the multiple axes control block (MC unit) and drive block (AMP unit) are reduced by using serial communication. (Fig. 1)
(2) Graphical design
  "PQ" was developed for the world market from the start of planning. As a result, both "PQ" Type R and "PQ" Type M are designed, appealing their concepts clearly in spite of functionality-prior design.
(3) Open architecture and networking
  SERCOS compliant with internal standard IEC61491 is used as the user interface. Accordingly, any components that comply with the standard can be freely selected to configure the system. In addition, although the conventional combination of single-axis amplifiers has required SERCOS optical link cable to be connected to each axis, in "PQ" system the cable needs to be connected to only one point (Fig. 2). This reduces the cost and also the size of the user's program because the alarm processing sequence among the axes that has been programmed by the user or other company, is executed by the batch control of the multiple-axes amplifier.
(4) Support for multiple types of actuator
  "PQ" supports not only the synchronous brushless servo motor operation, but also the induction motor and linear motor operation.
(5) Power supply variations
  Different types of power supply (PS) such as step-down converter (400 V input), power regeneration converter and resistive regeneration converter can be used for "PQ" Type M according to requirements.
(6) Built-in general purpose I/O
  An I/O unit is usually necessary when configuring a system, either a separate I/O driver or an additional I/O driver installed on the field bus. "PQ" has a built-in general purpose I/O with inputs for 32 channels (each axis 8 ch x 4) and outputs for 32 channels (each axis 8 ch x 4) as standard. Optional I/O module connections can be added as many as four nodes.

(7) Support for European and American markets

  The product conforms to the CE directive, for European markets and to UL and CSA standards for American markets. As a general-purpose I/O, a circuit is adopted that can be used both in the Europe where the wiring is positive-common, and in the U.S. where the wiring is negative-common.

(8) Total solution

  "PQ" amplifier enables competitive total solutions to be configured when combined with other Sanyo Denki products such as single-axis "PZ" amplifier, industrial PC "S-MAC PC", object-oriented control language "AML", and others.

6. Functions of PQ Amplifiers

(1) Main functions supported by SERCOS

* Indexing function (modulo)

  This function is for a indexing device, and converts the coordinates of the linear system to those of the rotary system. The size of coordinate per rotation can be freely set, and a target position on the specified rotary coordinate can be position-set with a short cut. It can be used for the input of internal encoder and external encoder.(2 channels)

* Measuring function (probing)

  When the positional relationship correction between the conveyor and workpiece controlled by a discrete system is desired. The positional relation between the actual workpiece position and the encoder position can be informed as follows. Inputting the output from workpiece position detecting sensor to the amplifiers I/O, and latching the encoders position data. Two channels with insulate inputs are supported for each axis.

* Home position return function (homing)

  The home position returning can be selected from the four patterns of the Z-channel, home switch, Z-channel, and home switch and preset. This built-in function enables to perform easy home position return, instead of conventional return through a controller.

(2) Real-time auto tuning function

  The load inertia is calculated during operation so that the optimum gain parameter can be selected in real-time. Thus, troublesome tuning for users is eliminated. The tuning level is divided into 11 steps.

(3) Support for fully-closed control

  In order to establish fully-closed control, inputs for external encoder signal are equipped. Supporting 2 axes. (for incremental use or for absolute use)

(4) Vibration suppression function

  The product has a low-pass filter and notch filters as standard to suppress mechanism vibration.

(5) Switching the control systems

  The various controls such as PID control of position, PI control and I-P control of the velocity loop can be switched depending on the application.

7. Conclusion

  Requests for open architecture and support for multiple interfaces in the field of FA are becoming stronger, particularly in Europe and the U.S. "PQ" marks the first step toward a multiple-axes amplifier that fulfills current requirements. We shall continue to develop products that satisfy our clients' expectations by improving the controllability of the multi-axes servo amplifier and improving functionality.

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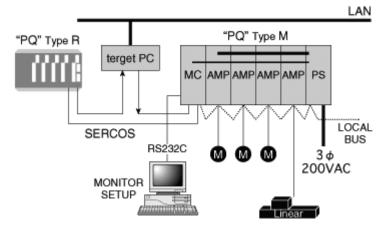**Photo 1 "PQ" Type R**

Photo 2 "PQ" Type M
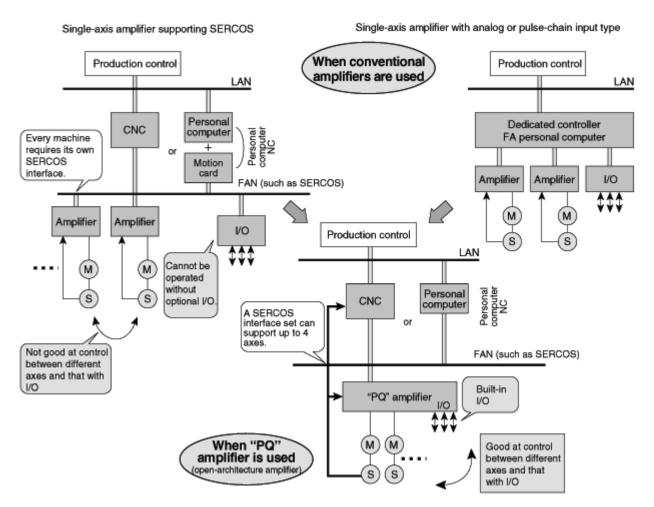
Fig. 1 Example of "PQ" configuration

Fig. 2 Comparison of configurations between conventional type amplifier and PQ amplifier