

## Introduction

Motion control systems consist of three main components: the controller, the amplifier and the motor itself. These three components must work together in harmony to ensure high performance and ease-of-use. The most common applications for these servo motor systems are in industrial machines and processes.

This article will examine the latest Yaskawa product offerings in these three areas. It will show how these products work individually, and how they work together in an integrated servo motor control system.

Special consideration will be given to features that allow quick installation and configuration, especially in applications where all three components are utilized.

Advancing on the design of the best industrial automation products, Yaskawa servo motor control systems provide end users with the tools and features needed to get a servo system up and running simply and quickly. For users with high performance requirements, fine tuning and other options extend capabilities.

The three product families covered include the MP2000iec Series machine controllers, the Sigma-5 servo amplifiers and the Sigma-5 servo motors.

## Machine Controller

In the past, most machine control systems consisted of two or more machine controllers. The first was typically a PLC or PC, and the second was one or more machine controllers. The PLC or PC was used for on/off control of various machine components, and for analog control of variable devices except variable speed motors.

The PLC or PC didn't have the specialized capabilities needed for interface to and control of a servo amp and motor, so one or more machine controllers were required. Each machine controller contained functionality limited to and specialized for control of servo amps and motors.

The programming languages in the PLC or the PC were optimized for machine control. Although it was generally possible to interface with and control servo amps and motors with a PLC or a PC, it was often cumbersome and impractical.

The machine controller was optimized for interface with and control of servo amps and motors and had limited capability for control of other components. This was especially true in the case of programming languages which were specifically designed for servo motor control.



MP2000iec Series Machine Controllers



Today, many machines utilizing servo motors can be controlled with one machine controller instead of two. This is most practical when the machine features one or more servo motors, and when control of these servo motors constitutes a major part of the control system. Yaskawa's MP2000iec Series of machine controllers fits this type of application perfectly as it can function as a stand-alone main machine controller without need of a primary PLC or PC controller.

Certain features and functions are required of the main machine controller in systems with one or more servo motors. First, is a highly developed interface to and control of servo amps/motors. Second is interface with and control of all other machine components outside of the servo amp/motors.

For servo amp/motor control, the MP2000iec Series employs and advances upon Yaskawa's decades of experience. In particular, setup and programming of servo amps/motors is simplified. This tight integration between the MP2000iec Series machine controllers and the Sigma-5 servo amplifiers and servo motors will be examined in more detail later in this article.

In addition to excelling at interface with and control of servo amps and motors, the MP2000iec Series machine controllers are ideal for control of other machine components. Control of a machine with a number of variable speed motors requires four main attributes: a capable control engine, extensive I/O options, open standards connectivity and an easy-to-use yet powerful programming language.

The MP2000iec Series control engine can handle up to 1500 discrete I/O, 100 analog I/O and up to 16-axis of motion. Operation times on the 240 MHz processor are in the nanosecond range, providing all the power needed for most machine and process control applications.

In addition to supporting a wide range of native Yaskawa I/O in both a local and remote mode, the MP2000iec Series can interface with remote I/O from leading third party suppliers like Opto 22, Phoenix Contact and Wago. Remote interfaces to third party I/O are via industry standard digital networks including EtherNet/IP, Modbus TCP/IP, and MECHATROLINK-II.

Open network connectivity to HMIs and other higher level visualization and computing systems are accomplished through the Ethernet 100BASE-TX/10BASE-T port via the EtherNet/IP, Modbus TCP/IP, or OPC Server protocols. Access to all web browsers is built-in as the MP2000iec Series feature a built-in web server along with Ethernet connectivity. The web server allows maintenance and other personnel to interface with the MP2000iec Series without the need for any special software.



Perhaps the most notable features of the MP2000iec Series machine controllers are the MotionWorks IEC Express and MotionWorks IEC Pro IEC61131-3 programming environments. MotionWorks IEC allows programming of the controllers in any one of five IEC 61131-3 programming languages. These five languages can be used in one machine controller program based on the requirements of the application and the preference of the programmer.

The five languages are Ladder Diagram, Structured Text, Function Block Diagrams, Instruction List, and Sequential Function Chart. MotionWorks IEC Express incorporates Ladder Diagram, Structured Text, and Function Block Diagram languages – making it well suited for less complex applications that only require one task. MotionWorks IEC Pro has all the features of Express, but also offers Instruction List and Sequential Function Chart languages plus 16 prioritized tasks giving users easier control of machine states.

Ladder Diagram is the world's most widely known and used industrial control language, and it is well suited for control of discrete I/O. Structured Text is often the best solution for mathematical algorithms and assignments, while Function Block Diagrams are ideal for motion control.

With MotionWorks, these languages seamlessly and predictably cooperate with one another. Variables and outputs from one program structure can be referenced by other programs, providing a powerful and easy-to-use automation development and execution environment.

The Function Block Diagram language in the MP2000iec Series controllers is particularly powerful because it contains custom motion control function blocks developed and proven by Yaskawa through decades of use. These powerful and field tested motion control algorithms comply with the PLCopen standard, allowing for seamless incorporation into the MP2000iec Series controller's IEC 61131-3 software programming environment.



The MotionWorks IEC software provides a high level configuration environment for Yaskawa servos, the latest of which is the Sigma-5 family of servo amps and motors.

### **Sigma-5 Servo Amps**

The Sigma-5 servo amplifiers deliver the highest performance in the industry with a wide range of models and options to match individual application requirements. Models are available rated at 120V, 240V or 480V from 50W-15kW with frequency response of 1.6 kHz. The amplifiers comply with EN954-1 Safety Category 3 and with IEC61800-5-2 Safe Torque Off.

Setup and tuning of the amps can be accomplished via three methods. First is autotuning with real-time adaptive load control, a function that allows users to get up and running quickly without manual tuning. Autotuning automatically adjusts for changes in load due to rotor inertia mismatches up to 20:1 and features a settling time of 100-150ms.

Second is advanced autotuning which brings settling time down to the 10ms level. Advanced autotuning provides for adjustment of the reference filter and feedback gain via the new feed forward gain adjustment function. The friction compensation function automatically cancels out the effect of friction on machine characteristics.

When fine tuning is a must, one-parameter tuning can tweak machine performance to settling levels between 0 and 4ms. Taken together, these three tuning methods provide users with a variety of options to fit virtually all applications.

The Fully-Closed Loop Option Module allows the user to close the position loop around a secondary feedback device placed near the motor load. This feature can help eliminate the effects of mechanical and thermal variances of mechanical components, resulting in more precise control and improved machine performance.

Three options are available for communications between a machine controller and a Sigma-5 amp. First, is analog voltage/pulse train, an industry standard for decades. Second, is MECHATROLINK-II digital communications, a high performance network included as standard on both the MP2000iec Series machine controllers and the Sigma-5 amps. Third, is the new EtherCAT Communication Option Module. The EtherCAT module implements the CANopen drive profile (CiA402) in EtherCAT real-time Ethernet communications. This allows the user to control a Sigma-5 amplifier with an EtherCAT master in a variety of different modes, including cyclic synchronous position, cyclic synchronous velocity, cyclic synchronous torque, interpolated position, profile position, profile velocity, or profile torque. Available EtherCAT system architectures include line, star, tree or daisy chain.



Sigma-5 Series Servo Amplifiers

Because EtherCAT masters are available from a number of different PLC and PC suppliers, the Sigma-5 Series servo amps can be used with a wide variety of controllers. The addition of EtherCAT provides open connectivity to the Sigma-5 Series and enables its use in myriad applications.

EtherCAT ([www.ethercat.org](http://www.ethercat.org)) is perhaps the highest performance Ethernet protocol available. High speed is an obvious advantage in many motion applications, but even when high speed is not needed, EtherCAT can provide other advantages.

Implementing faster than needed network performance never harms a control system. Even when speed requirements aren't stringent, a fast network reduces configuration effort since default settings are normally sufficient. This reduces the effort needed to set up and program a control system.

Superior overall performance, a wide range of available sizes and open network connectivity make the Sigma-5 Series servo amps the best choice for virtually all servo motor control applications, especially when paired with Sigma-5 servo motors.

### **Sigma-5 Servo Motors**

Many applications have needs for servo motors in a variety of styles including rotary, direct drive and linear. Depending on the exact requirement, one type of motor style will generally outperform other options and be the most optimal choice.

In the past, many designers compromised and used only one style of servo because they didn't want to introduce multiple amps and accompanying complexity. But Yaskawa eliminates the need to compromise by offering its servo motors in rotary, direct drive and linear styles – with all three types driven by the Sigma-5 family of servo amps.

Direct drive servo motors are designed for applications where the load is directly attached to the motor surface. Direct drive technology eliminates backlash, reduces the number of mechanical components, and provides a stiff mechanical system for highly dynamic applications.



SGMCS Direct Drive Servo Motor



Sigma Trac Linear Servo Motor

Linear motors excel in applications requiring very high speeds and rates of acceleration. A motion control system using linear motors will have very few moving parts, often resulting in lower maintenance. Linear motors don't require the space of a traditional motor, so the machine can be made smaller. The main limitation of linear motor systems is reduced ability to handle heavier payloads.

Rotary servo motors are the most commonly used and fit the widest variety of applications. The Sigma-5 Series of servo motors has taken the next technological step by using high-resolution absolute encoder feedback. Position information is transmitted to the amplifier allowing full error checking, eliminating position error caused by electrical noise and preventing runaway conditions. This all-digital feedback design enables the amplifier to automatically recognize the motor and optimize settings.

The Sigma-5 Series of servo motors encompasses power ratings from 50W to 15kW. Torque ratings span the range from 21-844 N-m, and both low and medium inertia models are available.

One of the major issues when applying servo motor systems has been setup and configuration, but many of these problems are eliminated because of the tight integration among the MP2000iec Series machine controllers and the Sigma-5 amps and servo motors.

### **Tight Integration Enables Ease-of-Use**

Many machine and process line builders are interested in upgrading their mechanical motion systems to servos, but are often wary because of perceived difficulties in setup and programming of servo systems. Yaskawa addresses these issues with a variety of features.

The MP2000iec Series machine controllers are supplied with MotionWorks IEC programming software. This software utilizes IEC 61131-3 standards to simplify programming, especially for motion control. The Function Block Diagram language included as one of the options in the programming software contains custom motion control function blocks developed and proven by Yaskawa through decades of use.

No controller stands alone, and integration at various levels is greatly eased by the open connectivity of the MP2000iec Series machine controllers. Integration to higher level components such as HMIs and PLCs is easily accomplished via EtherNet/IP and Modbus TCP/IP.

Connection to either third party Remote I/O available from a variety of suppliers is implemented via standard interfaces such as EtherNet/IP, MECHATROLINK-II and Modbus TCP/IP, and therefore requires no special programming or network configuration.

Interfacing for maintenance purposes is made simple via the built-in web server capabilities of the MP2000iec Series machine controllers. Instead of loading a proprietary and custom program on a laptop, maintenance personnel can simply access the machine controllers via any web browser.

Interface to Sigma-5 servo amps via the MP2000iec Series machine controllers provides a number of features that enable ease-of-use. The machine controller can operate local Sigma-5 programmable amplifier outputs. In addition to simplification, this feature reduces panel cost and space requirements for applications where just a few outputs are needed in the control system.

Controller Centric Commissioning is another feature enabled by the tight integration between MP2000iec Series machine controllers and Sigma-5 servo amps. When using the MECHATROLINK network, a machine can be configured from a single location, the machine controller, using only one software tool.



Sigma-5 Series Servo Amplifiers and Motors

When the Sigma-5 servo amps are paired with Sigma-5 servo motors, high-resolution absolute encoder feedback is provided as a standard. This all-digital feedback design enables the amplifier to automatically recognize the motor and optimize settings without the need for custom configuration, a feature that significantly adds to ease-of-use. In addition, the use of absolute encoders simplifies machine design by eliminating the need for home switches, cabling, and lengthy homing processes.

The Sigma-5 servo amps feature autotuning with real-time adaptive load control. This allows users to simply activate the autotuning feature to configure the operation of the amp and its associated servo motor. Autotuning provides control at a level of precision suitable for most applications, and further fine tuning can be accomplished as needed.

For the highest level of precision control, the Fully Closed Loop Option Module allows the user to close the position loop around a secondary feedback device placed near the load. This feature helps eliminate the effects of mechanical and thermal variances of mechanical components - allowing for more precise control and improved machine performance.



## **Conclusion**

Yaskawa offers a fully integrated motion control system with the MP2000iec Series machine controllers, the Sigma-5 servo amplifiers and the Sigma-5 servo motors. The tight integration among these three components offers the high performance of each product to be delivered with unprecedented ease-of-use.

The MP2000iec Series machine controllers now offer IEC 61131-3 programming, a worldwide standard. Yaskawa greatly extends the power and performance of the standard by including custom motion control function blocks.

The Sigma-5 servo amps are now completely open in terms of connectivity with the addition of EtherCAT. This protocol offers the highest performance of any industrial Ethernet bus, and it's widely accepted and implemented by a number of suppliers. The Sigma-5 servo amps include standard features such as vibration suppression and autotuning.

Sigma-5 servo motors are available in rotary, linear and direct drive versions. Each of these versions excels in different applications, allowing motion control system designers to pick the right motor for their particular needs.

Taken together, the MP2000iec Series machine controllers and the Sigma-5 servo amplifiers and servo motors set the industry standard for high performance and ease-of-use in motion control systems.