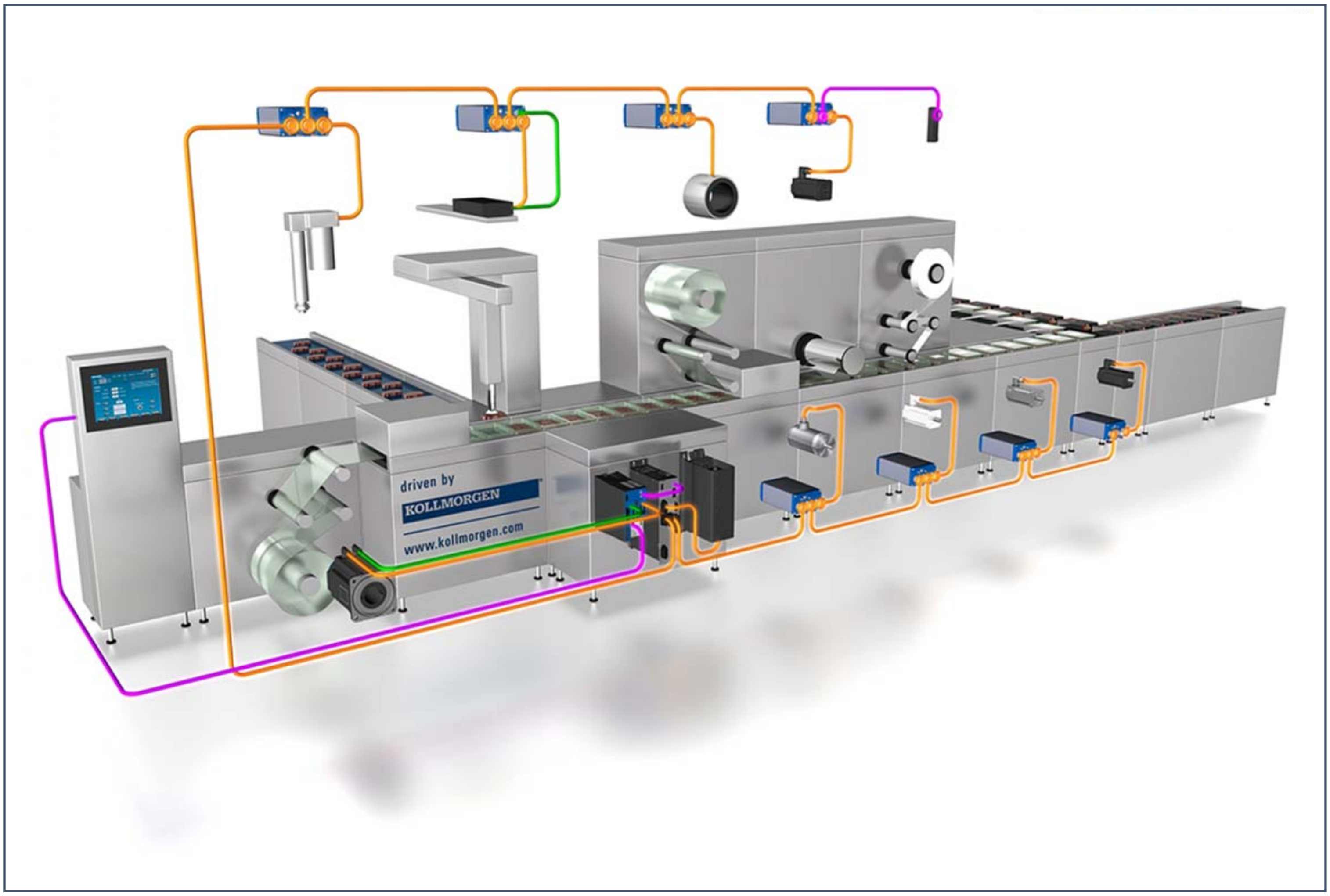

Getting Started Sizing & Selecting Servos:
Understanding the need for a system solution

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White Paper

Sizing and selecting a servo motor system for a machine design begins by understanding the components that make a servo motor or servo-drive system. Servo systems are closed-loop, controlling some desired motion. They incorporate a feedback device that provides constant information between the motor and drive to precisely control position, speed and torque to the mechanism being driven*.*

Usually, servo designs are highly dynamic systems involving rapid load accelerations and decelerations. They operate in all four quadrants, meaning they control torque and speed whether positive or negative.

Sizing a servo system is more than just selecting a motor for your machine. There are a variety of considerations when developing a solution, not only in the expected performance requirements, but also in elements such as the environment and connectivity. This paper focuses on a holistic approach to determining your best servo solution.

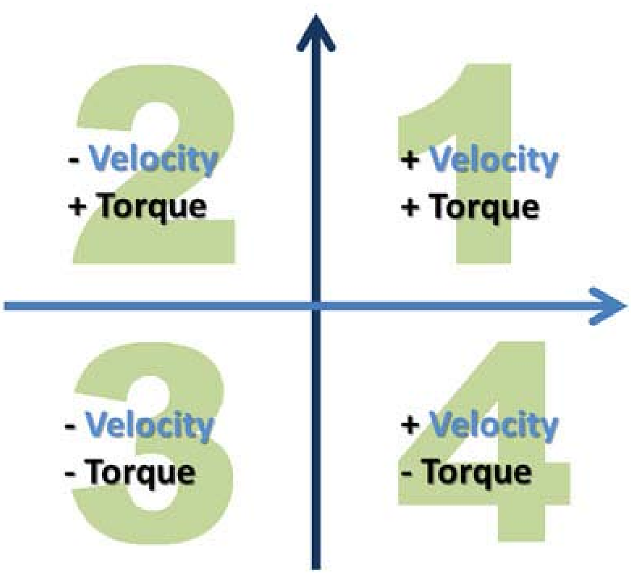

Figure A: *Servo applications will operate in all four operating quadrants*

Sizing a servo-driven design requires a system solution — in other words, a holistic approach that accounts for global mechanical, electrical and programming parameters. The system includes a definition of the mechanical load, motion profile (including positioning requirements), the servo motor characteristics, and the environment in which the motor and other components are placed; and especially where motors are running close to a constant velocity while effecting the manufactured product, the material being processed and/or the process itself.

Mechanical Load and Motion-Profile Parameters

Let's begin with an understanding of the implications of the mechanical load and motion requirements. Basic Newtonian physics assert that force (or torque in rotary terms) is proportional to the mass (rotary inertia) multiplied by the acceleration rate, whether positive or negative. Within the context of a motion design, a machine build has its own mass and the mass of the load being transported.

So, it's important to accurately define the mechanics — specifically, the masses in motion and the required motion profile. Mechanisms used to translate rotary motion to linear motion vary widely and depend on the kind of precision, loads, move dynamics and environments as to which is best.

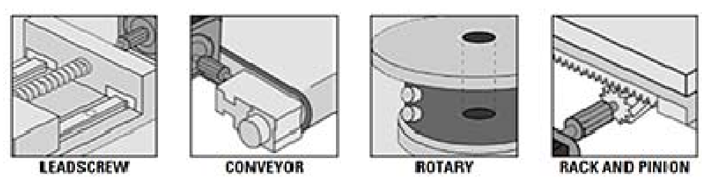

Figure B: *Application sizing programs offer various mechanical solution templates*

Once you understand the mechanism to be used, an understanding of the move dynamics is important to determine the best servo motor solution. Motion profiles are inclusive of not only the move from one point to another but also what functions might be occurring during that motion, such as thrust forces associated with machining of parts. Acceleration, traverse and deceleration, as well as dwell or rest periods, are included in the overall motion profile of the system. Indexing moves can be simply a triangle move, variable trapezoidal or 1/3-1/3-1/3 (the most efficient tied to RMS torque). Sizing and Selection tools are available to help the user build out a motion profile based on the motion requirements of the application. Most software tools, like Kollmorgen's Motioneering platform, provide a number of ways you can describe a move and assists in calculating acceleration rates, move time and distance, traverse and dwell times. Figure C shows a basic 1/3-1/3-1/3 profile with the introduction of 50% jerk to smooth out the acceleration rates. In this example, we chose to move 8 inches in 1 second using 50% jerk and a dwell of 2 seconds. The system calculated the move based on 1/3 of the time accelerating, 1/3 at traverse and 1/3 deceleration. Maximum speed was calculated by the tool at 720 in/min. You can see the "S" curve profile (based on the 50% jerk rate). Also, for this move, you can see the Thrust load (red line) was applied during the traverse portion of the move – this is where machining may be taking place for this move profile. The dwell period is also seen running this out to the 3 second mark. The dwell portion is quite important as all parameters related to this profile will be utilized to calculate the RMS torque which will be one measure we will use in selecting the correct motor. Along with the motion profile, it's important to understand the actual positioning requirements of the load regarding resolution, accuracy, and repeatability. This is directly affected by the feedback device selection and (more significantly) the mechanical assembly's amount of lost motion in the form of backlash and compliance.

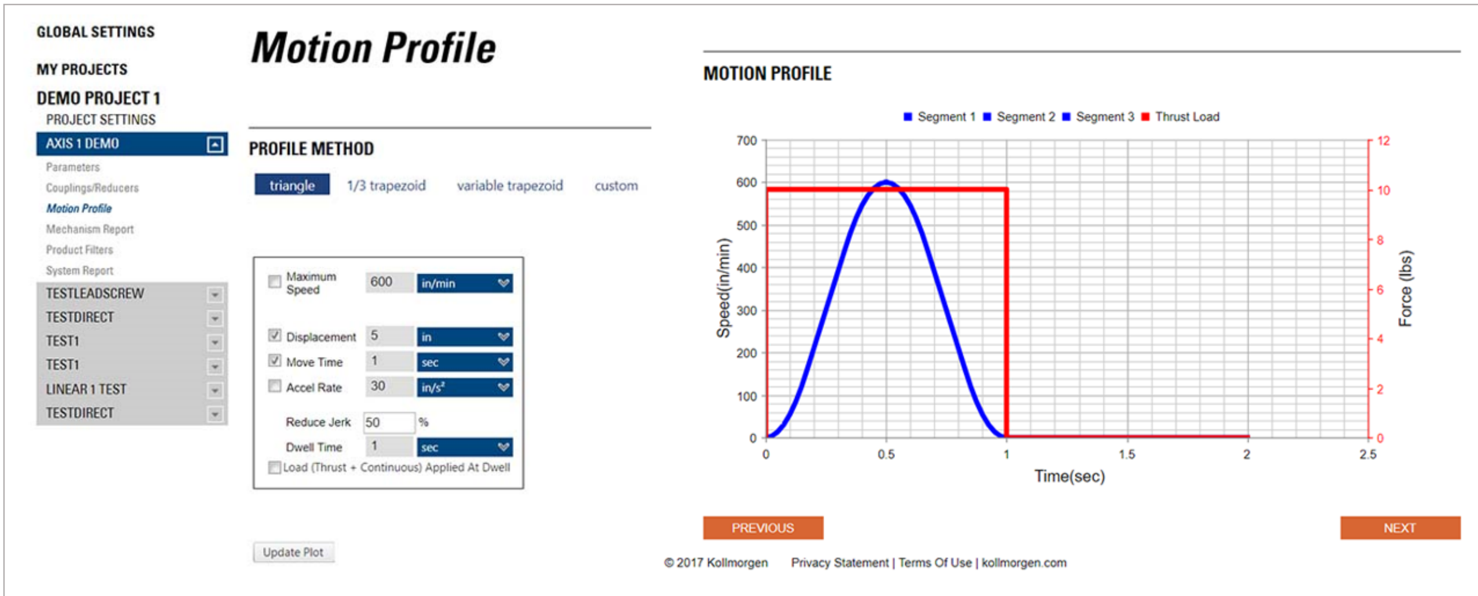

Figure C: *Typical motion profile output of an application sizing program*

Unless the design can utilize a direct-drive motor solution, it will include a mechanical transmission of some type. The rotary-to-linear power transmission (to transmute rotary motor output into axis strokes) might be through a pulley-driven belt or screw-based mechanism such as a ballscrew, for example. Rotary transmissions include gearboxes or belt-driven assemblies to function as speed reducers using pulleys of various sizes. In some applications, parts being moved make a significant contribution to the total moving mass. One special case is when a machine axis must move a changing mass — as in the case of robotic systems in dispensing or machining, for example. Here, the total load change can be a factor in the tuning of the servo drive.

The components in motion must have their inertias summed and reflected back to the motor shaft. In addition to the inertia, external forces, as well as friction and inefficiencies must be taken into consideration.

Environmental Considerations for Servo Designs

It doesn't end there. When specifying a servo design, only some available mechanisms will cost-effectively deliver the required motion, load carrying and accuracies. One consideration that is often overlooked is the environment in which the servo system will operate. Most servo motors are rated for operating in 40° C ambient conditions — which is a very warm environment, but typical of many factory and industrial settings.

Drive electronics aren't so forgiving of heat, and since they also are rated for a 40° C ambient, managing the temperature they operate in can become a challenge. Often, forced air cooling methods are required in control cabinets to maintain proper ambient conditions (temperature and humidity). So, considerations must be addressed for where the motors and drives are located. Motors, of course, mount or integrate directly into the machine to drive the mechanisms holding the load. In contrast, the drives in a centralized scheme are located within a control cabinet — which typically is cooled. Why is this of concern?

Manufacturers define motor performance in part by the ambient condition in which it will operate. As mentioned, many designers are assuming a motor is rated for a 40° C ambient, but occasionally motor specifications offered are rated at 25° C. So, care is advised when reviewing specifications to understand what ambient is referenced for the published rating. If the ambient temperature of where the machine will operate exceeds the rated ambient, the motor won't perform at its rated capability.

Other environmental conditions can threaten the motor paint and seals and other mechanical subcomponents. Dust, dirt, moisture, spray wash-down, hygienic requirements, explosive settings, vacuum environments and radiation all necessitate specialty servo motor features with physical characteristics tailored to the challenge at hand.

The Selection Process

A good portion of the upfront sizing effort in determining the motor/drive system muscle you need comes from the mechanics and environment. Now, as you select the final products, you must consider the rest of the system components that are included with that muscle. The mechanics and environment will continue to play on choices you make regarding feedback elements, cabling and ultimately the control architecture you choose.

Feedback Considerations and Servo Motor Characteristics

By definition, servo systems have feedback devices that measure velocity, position and other system parameters during operation. Manufacturers may have limited choices, but careful consideration of specific application parameters — including shock loading and positioning accuracy and repeatability — is essential. Resolvers tend to excel in harsh environments especially with higher shock loads. Resolvers are rotary transformers consisting of coils of wire wrapped around a core for both the stator and rotor portions. This architecture allows for higher temperature operation and is much more forgiving in high shock loads as opposed to encoders which likely contain a glass disc element.

Sinusoidal encoders offer high resolution —up to 24 bits and higher— for best positioning accuracy. Some hybrid feedback devices offer robustness of a resolver with improved resolution capabilities. These smart feedback devices are based on a resolver with an electric element that interprets the sin and cosine signals and converts them into a high-resolution digital signal which is passed to the servo drive to utilize in both velocity and position feedback.

The newest encoders today offer a variety of communication protocols (EnDAT, BiSS and DSL) and offer high resolution and noise immunity helping to achieve the best feedback signal possible to the servo drives and controllers.

Another feedback choice that is dependent on the application requirements is the need for absolute position feedback versus incremental. In a rotary system, once you complete a 360-degree rotation with a single-turn device, you start over. Whereas a multi-turn absolute encoder allows your system to know where it is, not only within the 360 degrees of a motor's rotation, but also how many times it made a complete turn in either direction. Thus, it knows exactly where you are positioned. This may be very important to know in conjunction with the positioning of tools and other axes. On the other hand, the simple incremental encoder identifies where you are in a single turn, but only after finding itself on a power-up cycle — thus, you will not know how many times you completed a cycle, or even your absolute position within 360 degrees of rotation on power-up.

Cabling

We've talked a bit about the servo motor and servo drive, but cabling between the two is important as well. Cable flexibility, as defined by its allowable bend radii, is a key consideration here — especially where cable travels with the axis.

Cable length may be limited by the type of feedback device considered. Cable parameters such as impedance, voltage drop, combined with the signal strength of the feedback device are key factors in length considerations. Some newer devices available on the market are transmitting serial information to the drive (such as DSL, EnDat and BiSS protocols) at very high transmission rates which again are affected by length, specifically impedance and signal to noise ratios. Even connectors play a role in the "feedback" loop as connectors need to be designed to handle the kinds of signals being generated from these devices. Another element of cable length related to the motor power is tied to the high switching frequencies involved in today's PWM drives. The noise is present in the motor power cable and as the cable gets longer and approaches a half wave length of the frequency riding on the cable, an antenna is created. Antennas like to transmit or receive information (in this case, noise) – This is not desirable in a high-performance system.

Figure D: *Feedback selection is an important of determining the precision of a given machine.*

Ultimate Parameter: Motion Controls and Networking – Centralized vs. Decentralized

A final consideration — and one that may spur reiteration of the holistic design process (as well as changes to the other specified components of the design) is the system architecture. An engineer must ask: Should I focus on a centralized control system with drives, controllers and supporting electronics packaged in a centralized cabinet, or would it be more beneficial and cost-effective to distribute the drives through the machine – a decentralized system approach? A machine with high axis count, where axes can be spread throughout the machine would be an ideal candidate for a decentralized solution. This approach can drastically reduce cable requirements, saving costs associated with long cable runs, along with the cable trays and carriers that would accompany these cables. In addition, moving the drives out on the machine reduces the size of the cabinet you would need to house control and support electronics – again, reducing cost, and reducing the cooling requirements in the cabinet. On the other hand, a compact lower axis count machine would not benefit as much over the traditional centralized approach.

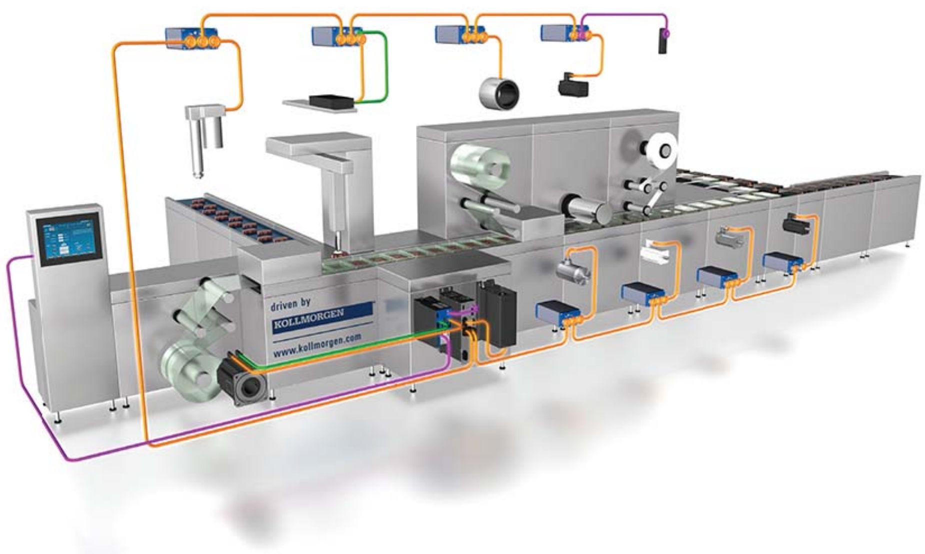

Figure F: *Machines may have a wide variety of motor technologies covering multiple processes*

Conclusion

There are many things one must consider when diving into an application when sizing servos, and we've covered many of those in this paper. Another choice that affects component selection is the control system. The type of control is usually dictated early in the machine design discussion and depends on a wide variety of factors. Control choice tends to lock in the fieldbus communication selection as well. These topics are left for a future discussion.

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Since its founding in 1916, Kollmorgen's innovative solutions have brought big ideas to life, kept the world safer, and improved peoples' lives. Today, its world-class knowledge of motion systems and components, industry-leading quality, and deep expertise in linking and integrating standard and custom products continually delivers breakthrough motion solutions that are unmatched in performance, reliability, and ease-of-use. This gives machine builders around the world an irrefutable marketplace advantage and provides their customers with ultimate peace-of-mind.

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