Reaching Full Potential

In a short time, mechatronics has evolved into a universally accepted engineering concept. Mechatronics integrates mechanics with electronics—and with engineering itself. The result is expanded technological capabilities and assembly-line successes like the Cartesian multi-axis robot. Because mechatronics allows much more flexible automated production, users can precisely control parameters such as weight, speed, reach, and work envelope. That’s why mechatronics can be the answer to a wide variety of design challenges.

But getting the right answers requires asking the right questions—from the very first stage of a design. A mechatronics solution is a 3-stage ongoing process:

- **Design**—configuring the system
- **Mechatronic Design Tips**
  - **Keep envelope restrictions in mind.** Use 3D simulation at the start to avoid reconfiguring system elements later in the project.
  - **Find a proper protocol.** Be careful when marrying controls and drives from different sources. Ensure that compatible off-the-shelf control solutions are available for system expansion or reconfiguration.
  - **Consider the implications of specifications.** Specifications such as motor size or cleanroom class can have powerful implications for a mechatronic system. Make sure all specifications are addressed at the design phase.
  - **Don’t forget cable management.** This often-overlooked step can prevent last-minute scrambles to avoid interference with motion.
  - **Find the right tool for the job.** Identify the controller performance needed.
Proper design begins with determining mathematical factors such as payload, travel distance, desired speed, and sizing of axes. Bosch Rexroth developed “LOSTPED”—a multi-step analysis process to help designers gather information for specifications. LOSTPED stands for Load (the weight or force applied), Orientation (direction each axis is mounted), Speed (and acceleration), Travel (distance and range of motion), Precision (repeatability or positioning accuracy), Environment (operating conditions), and Duty cycle (duration the machine will run; Example: 24 hrs./day, 5 days per week). In the automotive assembly application described above, duty cycle and assembly line speed are crucial in determining insertion arm size, motor size and logic control, along with many other key factors. To help answer these questions, Bosch Rexroth developed “LOSTPED”—a multi-step analysis process to help designers gather information for specifications. LOSTPED stands for Load (the weight or force applied), Orientation (direction each axis is mounted), Speed (and acceleration), Travel (distance and range of motion), Precision (repeatability or positioning accuracy), Environment (operating conditions), and Duty cycle (duration the machine will run; Example: 24 hrs./day, 5 days per week). In the automotive assembly application described above, duty cycle and assembly line speed are crucial in determining insertion arm size, motor size and logic control, along with many other key factors.

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The LOSTPED concept is a good first step towards a true mechatronics solution. Getting all the way there requires a multidisciplinary focus—to root out potential difficulties before they grow into time-consuming, costly and distracting problems. Let’s look at some specific mechatronics challenges—and some tips for handling them.

Design Challenges and Tips

- **Keep envelope restrictions in mind.** Work envelope restrictions (including walls, supports, and safety barriers) need to be taken into consideration to avoid physical interference. The difference between length of a module and length of stroke to accomplish a specific task.
- Integration—determining how components work together.
- Implementation—getting optimum value in daily operations, and preparing for future changes.

As an example, consider the parameters involved in an application such as insertion of pins in automobile underbodies traveling on an assembly line. Proper design begins with determining mathematical factors such as payload, travel distance, desired speed, and sizing of axes. Then there are questions of machine control, motor size to deliver proper speed and torque, and even the operator HMI. There’s also the key question of how much it all will cost.

Using 3D simulation during the design phase of the project can prevent the need for reconfiguring system elements later in the project.
is also crucial, especially when selecting linear actuators. A rodless actuator’s “dead length” means the actuator’s stroke is shorter than the apparent length of the cylinder. The best approach is to use a 3D simulation, rather than reconfigure system elements later in the project.

• **Find a proper protocol.** Approach with caution the marriage of controls and drives from different sources—it can lead to problems, especially when using off-the-shelf protocols such as PROFIBUS, DeviceNet or Ethernet. Some off-the-shelf solutions, such as Bosch Rexroth’s IndraControl components, can communicate with many proprietary controllers, but this may not be true of all solutions. That means problems may arise if a controller running DeviceNet is added to a platform running PROFIBUS. Similarly, if your plant runs Ethernet, you may not be able to “plug in” a component from any vendor. During the specification phase, you should ensure that compatible off-the-shelf control solutions are available for system expansion or reconfiguration.

• **Consider the implications of specifications.** Specifications can have powerful, difficult-to-foresee implications for mechatronics. For example, a 480 V 3-phase motor may be ideal for a servo application, but not if your drive amplifier is only capable of 220 V—which may require retrofitting a transformer. A change from Class 1000 to Class 100 semiconductor production clean room specifications may result in the need for 3rd party specification.

• **Build in cable management.** Often, this is the last challenge addressed, leading to last-minute scrambles to avoid interference with motion and parts pickup. Cable management for a gantry pick-and-place application should be one of the first factors considered. Some solutions, such as Bosch Rexroth’s camoLINE, offer predefined cable management and 3D modeling, letting you “drop in” components to ensure all components work cleanly together.

The circular interpolation path and identify the controller performance you need; that in turn will guide the selection of drives, power requirements, I/O and other elements to achieve the full performance.

Following some basic tips like these can help you avoid common—and costly—problems like either overengineering and oversizing machines (resulting in heavy-duty capabilities that are rarely if ever used) or undersizing machines (not accounting for occasional increases in payload or run speed). Either situation might result in higher automation costs, which might discourage implementation of mechatronics—another reason why asking detailed questions is essential.

**Integration**

Mechatronics is clearly a cross-disciplinary science, requiring expertise in mechanical and electrical engineering as well as electronics and computerization. But few engineers have a background in all these disciplines. So end users who have expertise in one particular area (such as electrical engineering) may end up doing on-the-job training in other aspects of mechatronics, or trying to learn how to incorporate components from an unfamiliar manufacturer.

One effective solution is to use the services of an integrator who specializes in mechatronics and is experienced in blending mechanics and electronics. Cross-disciplinary integrators
are becoming more common as mechatronics applications expand, and the trend toward cross-disciplinary integration skill is consistent with the current industry focus on accomplishing more with fewer people.

Integration can act as a “force multiplier,” extending the capabilities of existing technology to create quantum leaps in production efficiency, reduced downtime, and cost savings. For example, an automotive production line can be made many times more productive by substituting different control commands for retooling, and an outboard support axis added to a 3-axis Cartesian robot creates a gantry solution. Many similar solutions are possible for designers who adopt a multidisciplinary, full-system approach.

Implementation: The Future Starts Now
After integration, the final step is implementation. But the final step needs to be well-planned early in the process, or the result can be significant delays and added machine or production line costs. Avoid future problems by clearly defining the roles and responsibilities of integrator and customer. That can be a challenge in a process that blends a number of different engineering disciplines to create an integrated solution. The key is communication, right from the beginning—including detailed questions. For example, regarding system adjustments or changes, what is the responsibility of the integrator and what can be done by onsite personnel? The answers should be carefully documented to head off potential problems before they start.

Of course, no one can foresee the future. But good implementation envisions the context in which a mechatronics solution will operate.

Summary
As a cross-disciplinary process, mechatronics demands integrated thinking to go with integrated engineering. Machine designers and engineers need the ability to envision the day-to-day operation of assembly line functions, including the working environment and the blending of electronic protocols, to anticipate and head off potential disciplines. Engineers must also be prepared for the reality of cross-disciplinary requirements that may call for an integration specialist to get all the components working together for a complete solution. Finally, in order to implement the solution, the integrator and the end user must clearly communicate their roles and responsibilities. For mechatronics to be truly successful, the development process must involve not only mechanical and electronic elements, but process elements as well: the key phases of design, integration, and implementation.