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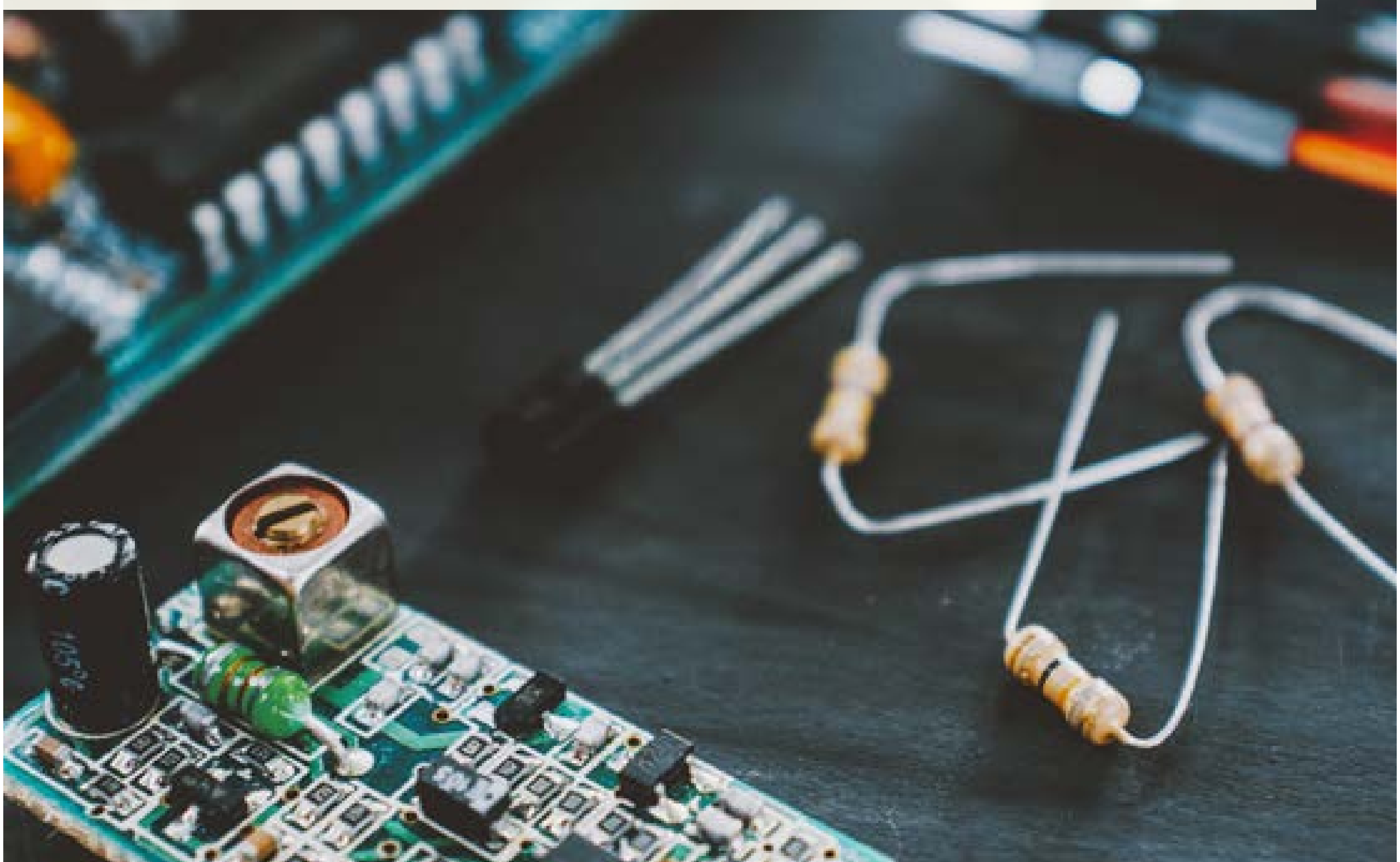
Effective Strategies for Overcoming Common Control System Design Challenges

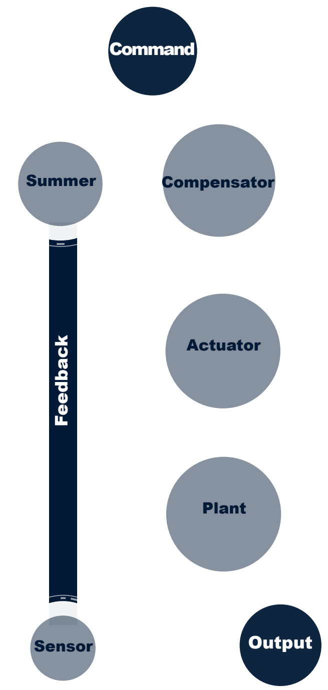


Control systems are a critical component of many modern engineering designs. They are used to regulate and maintain the behavior of physical systems, such as industrial processes, power systems, and transportation networks. Designing an effective control system is a complex process that involves a wide range of technical and non-technical challenges. In this white paper, we will explore some of the common challenges that engineers face when designing a control system and provide proven strategies to overcome them.

Section I:

What is a Control System?

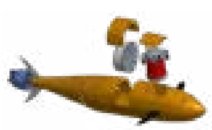
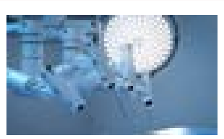
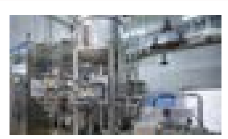
A control system is a set of components and processes that work together to manage, regulate, and control the behavior of a system. All control systems, such as a mechanical governor on an engine or a digital thermostat on an electrical heater, are designed to ensure the system behaves in a desired manner by regulating its inputs, processes, and outputs.



Where are Control Systems Used?

Control systems are widely used in applications where it is necessary to maintain stability and optimize performance of a system. Examples of control systems include thermostats that regulate the temperature in a room, traffic lights that control the flow of traffic on a road, and feedback control systems that regulate the speed of a motor.

Control systems are found in equipment and devices we encounter every day, including:

Autonomous Vehicles 	Industrial Automation 	Climate Control 
Smart Appliances 	Medical Diagnostic Equipment 	Aerospace & Aircraft 
Surgical Robotics 	Water Treatment 	Solar Energy 

Why Design and Use a Control System?

On the most basic level, engineers will employ a control system to ensure a particular response to a standard input, or the return to a desired state when a system experiences a disturbance. Well-designed controls can be used to return additional product performance benefits, including:

Increased Efficiency: A well-designed control system can optimize and automate processes, leading to improved efficiency and productivity. The system can detect inefficiencies and errors and take corrective action to improve performance.

Consistent Quality: Control systems can ensure consistency in the output of a process, machine or system. By regulating and monitoring key variables, the system can maintain a consistent level of quality, which is important for meeting customer demands and regulatory requirements.

Reduced Costs: A control system can help reduce costs by minimizing waste, reducing energy consumption, and preventing errors that may result in production downtime, rework, or scrap.

Enhanced Safety: Control systems can improve safety by monitoring and controlling processes in hazardous environments. By automating processes, the system can reduce the risk of human error and prevent accidents.

Real-Time Monitoring: Control systems can provide real-time data on the status of a process, machine, or system. This allows operators to quickly identify and resolve issues before they become major problems.

Scalability: Control systems can be designed to be scalable, allowing for easy expansion or modification of processes as needed. This makes them ideal for use in industries where production requirements may change over time.

What is the Importance of Robust Control System Design?

Developing a robust control system will set you apart from your competition, both in product performance and in results for your business. Success with maximizing product development returns comes from experience and expertise in control systems, both in understanding existing technology and in investing in the right solutions. Successful control system design is crucial to developing robust (and profitable) products, so make sure you have access to the knowledge and capabilities to make that happen. If you're unsure as to whether you or your team have those skills, your best option is to partner with a team that has the expertise to overcome control system design challenges and ensure your outcomes meet the potential of your project.

Section II:

Common Challenges in Designing a Control System

Complexity: Control systems are inherently complex, and the number of variables that need to be considered can be overwhelming. Designers must account for a range of factors, including system behavior, input and output signals, control algorithms, and environmental factors. To overcome this challenge, designers should use a systems engineering approach. This involves breaking the design process down into smaller, more manageable stages, and creating a clear framework for decision-making.

Complexity in an electro-mechanical control system is mentioned in the composition of its name: 'electrical' and 'mechanical'. They are in fact two distinct sub-systems with individual equations that the describe them, each of which is modelled separately. An engineer will need to thoroughly understand each subsystem before designing them into the larger model that is the complete control system.

Uncertainty: Control systems must be designed to operate reliably in a range of conditions. However, there is always some uncertainty about how a system will behave in different scenarios. This uncertainty can make it challenging to design a control system that is both effective and robust. To overcome this challenge, designers use a range of modeling and simulation techniques to test their designs under different conditions.

This uncertainty is exemplified with the specifications for motor inductance and resistance, which can vary widely. Additionally, mechanical loads are often not precisely known. Designing to the extreme ends of value ranges to be certain that your control system is stable under all those conditions is often the first step, with additional design needed when tested. After testing on the actual system, engineers can 'fine tune' the control system to better meet the system needs, a process which is often costly and time consuming.

Time Constraints: Designers of control systems often face tight deadlines, particularly in highly competitive industries where delays can have significant financial and safety implications. This time pressure can make it difficult to ensure that the design process is thorough and that all potential issues are identified and addressed. To overcome this challenge, designers should prioritize their efforts based on the potential impact of different design choices.

For example, in a design situation with where time is constrained, an accurate model of the plant (physical device to be controlled, such as an engine compressor) is extremely beneficial. If the plant can be effectively modelled and understood, then control algorithms can be developed and tested while the hardware is under development. When the hardware arrives, it takes significantly less time to get the control systems performance to an acceptable level.

Complexity of Software: Many control systems rely on complex software algorithms to operate effectively. However, designing and testing these algorithms can be challenging, particularly when dealing with large datasets. To overcome this challenge, designers should use software tools that allow them to model, test, and optimize their control algorithms efficiently.

In addition, some software tools will generate actual code that can be directly downloaded into the processor. This can be of great value during the build process, provided the engineer is familiar with these tools

Lack of Standardization: There is no single standard for designing control systems, and different industries and organizations may have different requirements and expectations. To overcome this challenge, designers must work closely with their end customer to understand the application.

If the application is a medical device, emphasis on safety can put tight limits on a device's motion. To prevent excessive motion (such as overshoot or oscillations due to an underdamped control system that could result in harm to the user), the engineer would want to bias to overdamped to eliminate the excessive motion and support a reduced risk to the user. In contracts, if the design is a robot trying to achieve position for automation in a factory, fast and precise response would be the parameter to optimize.

Strategies for Overcoming Common Control System Design Challenges

The discipline of Control Systems Engineering focuses on modeling a diverse range of systems (e.g. mechanical, thermal, optical etc.) and the design of controllers (or control algorithms) that will cause these systems to behave in the desired manner, regardless of disturbances from the external environment.

Thinking strategically about the application requirement, and utilizing knowledge gained through multiple successful projects, an expert Control Systems Engineer will design a solution to overcome common control system challenges. Here are several tools they may employ in the process:

Use a system engineering approach: Using a systems engineering approach can help designers overcome complexity and break the design process down into smaller, more manageable stages while maintain focus on the overall system architecture. This approach involves creating a clear framework for decision-making, which can help designers stay focused and ensure that all relevant factors are considered.

Boston Engineering used this approach when designing controls in a robotic vehicle application, where many disciplines such as mechanical, electrical, controls, and software were involved to overcome the particularly complex challenges. By employing a systems engineering approach and a

robust design approach, the integration proceeded quickly, allowing us to get through testing and meet the customers' expectations.

Use modeling and simulation techniques: Modeling and simulation techniques can be used to design and test control systems under different conditions, helping to identify potential issues before they arise. This can help designers to create more robust and effective designs.

In a similar robotics application where the vehicle was operating on both a horizontal and vertical surface, Boston Engineering employed modeling and simulation to understand the relevant forces. Since the forces are significantly different for horizontal and vertical planes, modeling and simulation provided significant insight for the necessary performance of the actuators. These models provided important feedback for the mechanical design, which resulted in a successful outcome on the prototype build.

Use software tools: Using software tools that allow designers to model, test, and optimize control algorithms efficiently can help to reduce the complexity of the design process. These tools can help designers to create more effective and robust control algorithms and reduce the risk of errors and malfunctions.

A system model was developed and implemented by Boston Engineering in a precision fluid handling system that required resolutions at the nanoliter level. The tool proved quite efficient and effective: once the model was validated with basic testing, and the resulting control scheme implemented in hardware, only minor changes were needed to realize the desired performance. As an additional benefit, C code was directly created from theis tools to implement the control algorithm.

Understand the requirements and standards from industry organizations and regulatory bodies: In many cases, the required standards and regulations for a new product will be clear. If not, working closely with industry organizations and regulatory bodies can help designers to ensure that their designs meet all relevant standards and requirements. This can help to reduce the risk of legal and financial liabilities and ensure that control systems operate safely and effectively.

In the rapidly developing spaces of personal assist robots and exoskeletons, Boston Engineering uses this approach. Standards and 'best practices' are evolving, and by working with Nationally Recognized Testing Laboratory (NRTL), we were able to define appropriate safety standards that would apply to the product under development.

Conclusion

Designing a control system is a complex and detailed process that involves a wide range of technical and non-technical challenges. In this white paper, we have explored some of the common challenges that designers face when designing a control system and provided strategies to overcome them. Remember that seeking help from experts or consultants specialized in control system design will provide valuable insights, enhance your product's performance, and ensure the safety and efficiency of your product.

About the Authors

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Frank holds mechanical and electrical engineering degrees from Worcester Polytechnic Institute and Northeastern University. Frank has a successful track record of bringing low- to high-volume projects from specification and concept through to manufacturing in the industrial, commercial, and consumer product markets.

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Bob holds electrical engineering degrees from Worcester Polytechnic Institute and embodies skills and experience from several industry segments. His career has focused on the industrial and semiconductor sectors, further the breadth and knowledge of our team.

About Boston Engineering

Making a meaningful impact drove us to start the business in 1995 and it has driven every project since. From designing advanced products and technologies to accelerating time to market, Boston Engineering thrives on solving tough client challenges. We provide product design and engineering consulting from concept development through commercialization. Clients benefit from our deep product development capabilities, focused industry expertise, and ISOcertified quality management system.

About Boston Engineering Control Systems Development

Boston Engineering is a leader in the development of custom control systems. Our integrated, cross functional team of electrical, software, and mechanical engineers will advise, direct, and manage any control system development project. Whether the challenge is to design a new control, increase reliability, improve performance, or synchronize responses, Boston Engineering thrives on solving the toughest challenges. From initial design consulting to turnkey product delivery, Boston Engineering experts support all phases of the Control System development cycle.

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