1 HISTORY OF AUTOMATIC CONTROL

The first applications of feedback control appeared in the development of float regulator mechanisms in Greece in the period 300 to 1 B.C. [1, 2, 3].The water clock of Ktesibios used a float regulator.

An oil lamp devised by Philon in approximately 250 B.C. used a float regulator in an oil lamp for maintaining a constant level of fuel oil.

The first feedback system to be invented in modern Europe was the temperature regulator of Cornelis Drebbel (1572–1633) of Holland [1]. Dennis Papin [1647–1712] invented the first pressure regulator for steam boilers in 1681. Papin's pressure regulator was a form of safety regulator similar to a pressure-cooker valve.

The first automatic feedback controller used in an industrial process is generally agreed to be James Watt's flyball governor, developed in 1769 for controlling the speed of a steam engine [

TABLE 1: Selected Historical Developments Of Control Systems

1769	James Watt's steam engine and governor developed.The Watt steam engine is often used to mark the beginning of the Industrial Revolution in Great Britain. During the Industrial Revolution, great strides were made in the development of mechanization, a technology preceding automation.
1800	Eli Whitney's concept of interchangeable parts manufacturing demonstrated in the production of muskets. Whitney's development is often considered to be the beginning of mass production.
1868	J. C. Maxwell formulates a mathematical model for a governor control of a steam engine.
1913	Henry Ford's mechanized assembly machine introduced for automobile production.
1927	H.W. Bode analyzes feedback amplifiers.
1932	H. Nyquist develops a method for analyzing the stability of systems.
1952	Numerical control (NC) developed at Massachusetts Institute of Technology for control of machine-tool axes.
1954	George Devol develops "programmed article transfer," considered to be the first industrial robot design.
1960	First Unimate robot introduced, based on Devol's designs. Unimate installed in 1961 for tending die-casting machines.

1970	State-variable models and optimal control developed.
1980	Robust control system design widely studied.
1990	Export-oriented manufacturing companies emphasize automation.
1994	Feedback control widely used in automobiles. Reliable, robust systems demanded in manufacturing.
1997	First ever autonomous rover vehicle, known as Sojourner, explores the Martian surface.
1998–	Advances in micro- and nanotechnology. First intelligent micro-machines are developed and functioning nano-machines are created.

2 ENGINEERING DESIGN

Engineering design is the central task of the engineer. It is a complex process in which both creativity and analysis play major roles.

Design is the process of conceiving or inventing the forms, parts, and details of a system to achieve a specified purpose.

Specifications are statements that explicitly state what the device or product is to be and do. The design of technical systems aims to achieve appropriate design specifications and rests on four characteristics: complexity, trade-offs, design gaps, and risk.

Complexity of design results from the wide range of tools, issues, and knowledge to be used in the process. The large number of factors to be considered illustrates the complexity of the design specification activity, not only in assigning these factors their relative importance in a particular design, but also in giving them substance either in numerical or written form, or both.

The concept of **trade-off** involves the need to make a judgment about how much of a compromise can be made between two conflicting criteria, both of which are desirable.

- ⇨ The design process requires an efficient compromise between desirable but conflicting criteria.

In making a technical device, the final product generally does not appear the same as it had been originally visualized. The inability to be absolutely sure about predictions of the performance of a technological object leads to major uncertainties about the actual effects of the designed devices and products. These uncertainties are embodied in the idea of unintended consequences or **risk**.

Risk: Uncertainties embodied in the unintended consequences of a design.

- ⇨ The result is that designing a system is a risk-taking activity.

Design gaps are intrinsic in the progression from the initial concept to the final product.

The main approach to the most effective engineering design is parameter analysis and optimization.

Parameter analysis is based on;

(1) identification of the key parameters,

(2) generation of the system configuration, and

(3) evaluation of how well the configuration meets the needs.

These three steps form an iterative loop.

Once the key parameters are identified and the configuration synthesized, the designer can **optimize** the parameters.

3 CONTROL SYSTEM DESIGN

The design of control systems is a specific example of engineering design. The goal of control engineering design is to obtain the configuration, specifications, and identification of the key parameters of a proposed system to meet an actual need.

The controller design problem is as follows: Given a model of the system to be controlled (including its sensors and actuators) and a set of design goals, find a suitable controller, or determine that none exists.

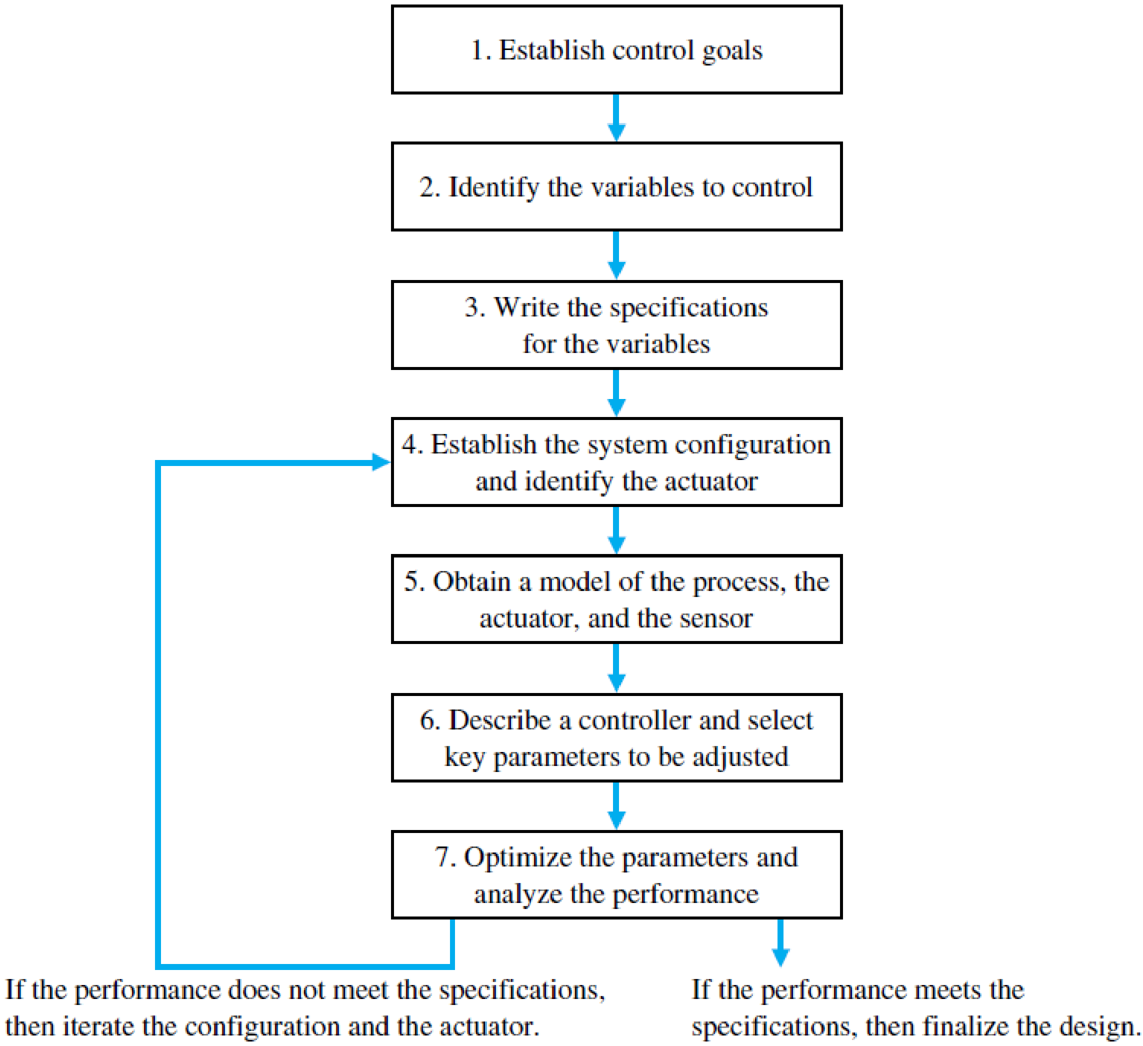
As with most of engineering design, the design of a feedback control system is an iterative and nonlinear process.

A successful designer must consider the <u>underlying physics of the plant under control</u>, the control design strategy, the controller design architecture (that is, what type of controller will be employed), and effective controller tuning strategies.

In addition, once the design is completed, the controller is often implemented in hardware, hence issues of interfacing with hardware can surface. When taken together, these different phases of control system design make the task of designing and implementing a control system quite challenging.

Open-loop control system: A system that utilizes a device to control the process without using feedback. Thus the output has no effect upon the signal to the process.

Closed-loop feedback control system: A system that uses a measurement of the output and compares it with the desired output.



1. Establish control goals
2. Identify the variables to control
3. Write the specifications for the variables
4. Establish the system configuration and identify the actuator
5. Obtain a model of the process, the actuator, and the sensor
6. Describe a controller and select key parameters to be adjusted
7. Optimize the parameters and analyze the performance
If the performance does not meet the specifications, then iterate the configuration and the actuator.
If the performance meets the specifications, then finalize the design.